FOREST SURVEYING

PART I

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FOREST SURVEYING

PART I

The Use of Steel Tape, Compass, Abney Level and Aneroid Barometer in Forest Surveying and Mapping

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PREFACE

Forest surveying is unique in land measurement. It is almost invariably done under adverse topographic conditions. It, therefore, requires a somewhat different approach to training than is usually given in engineering curricula. While basic principles are the same regardless of topography, the forestry student should receive his field training on rough terrain in order that he may become acquainted with the additional problems encountered.

Part One of Forest Surveying is designed to meet the requirements of an introductory course in forest engineering. It is by no means intended to cover the entire field. The text deals with the less precise and less expensive methods of forest surveying, i.e., the measurement of distance by steel tape and pace, direction by compass, and elevation difference by abney level and aneroid barometer. Much of the material set forth is treated with insufficient detail in standard surveying textbooks.

The precise methods of surveying, as described in stand ard surveying texts, are omitted. No attempt is made to explain the use of the engineer's transit and level in forest surveying, nor to discuss stadia, plane table, triangulation, celestial observation, public land surveying, and route surveying.

Section I of Chapter V does little more than outline forest mapping, as it is not a part of the course for which this text is devised. The paragraph on public land survey merely lists references. While the forester needs to be thoroughly versed in public land survey laws, complete treatment of the subject is beyond the scope and purpose of this text.

Topographic mapping is included in the second section of Chapter V for the purpose of giving the student the opportunity to apply his knowledge of the basic tools. In this section one method of mapping is detailed from start to finish.

Trigonometric functions and abney tables are included at the end of the text for use in solving the various problems encountered in this type of work.

The author wishes to acknowledge his indebtedness to Professor H. R. Patterson, head of the department of forest engineering at Oregon State College and W. A. Davies, associate professor of forest engineering for technical counseling, and to Dan D. Robinson, assistant professor of forest management for editorial assistance.

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FOREST SURVEYING

PART I

CHAPTER I. INTRODUCTION

Section I. General.

1. Surveying is the art of measuring angles, directions and distances and of establishing points. It is necessary to make mathematical calculations and to graphically portray the information on maps or other types of diagrams. Thus the process of surveying may be divided into field work and office work.

Surveys are used mainly to establish boundaries or furnish information for a plan.

2. Requirements of a good surveyor. Technical knowledge and skill are not the only requirements of a good surveyor or engineer. He should also have common sense and good judgment, and should accept his responsibility for honesty and accuracy. He should maintain the attitude of a scientist; that no result is trustworthy until every reasonable test has been made. Traits of character are more important in determining the success of a surveyor or engineer than technical knowledge or skill.

3. Solution of field problems. After acquiring a reasonable degree of technical knowledge and skill, one must develop the ability to use good judgment, common sense, ingenuity and flexible methods in keeping with the accuracy desired. The student of surveying is aided in acquiring technical knowledge and skill, but the development of the other essential qualities is almost entirely his responsibility.

4. The less precise surveying instruments. In surveying we must decide if we are to use extremely accurate instruments with resulting greater costs to a project, or if less accurate instruments will suffice, thus speeding up the time element and consequently reducing the cost. The use which is to be made of the results of a survey will help us in making this decision.

This text is confined to the treatment of what are sometimes called the less precise instruments, i.e. the steel tape or pace to measure horizontal distance, the compass to measure angles and direction, the aneroid barometer to measure difference in elevation and the abney to measure indirectly the elevation difference and horizontal distance. While the steel tape is often used for extremely precise measurement when used with auxiliary equipment, the accuracy limits of the abney and compass used in conjunction with the tape preclude the necessity of splitting hairs.

There is one common weakness, however, in the student who is learning to use these less precise instruments. Once he has barely acquired the basic mechanical skill of using the tools, he tends to lapse into carelessness, particularly with regard to the use of the steel tape. To avoid this mistake one must realize that less precise work does not mean careless work. Figures carried to the nearest foot and to the nearest quarter of a degree will give satisfactory results if the surveyor has done consistent work throughout the project. Errors produced are compensating if care has been used in the field work. The greatest and most illusive errors are produced by personnel and not by the instruments.

The advantages of these instruments lie in the speed with which they may be used. Here again the student will get into trouble if he fails to learn fundamentals first. He must concentrate on the performance of accurate work and speed will develop automatically after sufficient practice.

Section II. Field Notes.

5. General. Field notes are permanent written records of surveying taken at the time the work is done in the field. They should be in such form and clarity that anyone else may readily interpret them. If the record of the field work is illegible or unreliable, the survey, no matter how carefully done, has been a complete waste of time, energy and money.

In general the following suggestions apply :

a. Use a well-pointed 3-H or 4-H pencil. A piece of sandpaper taped in the back of the book is handy to keep the pencil sharp.

b. Make a neat title on the cover showing the owner or company directing the survey.

c. Leave several pages in the front of the book for an index of the problems done in the field. Always keep the index up to date.

d. If the page of notes becomes illegible or if celluloid sheets are used for recording notes in wet weather, make a copy of the data while information is still fresh in mind. Then mark it COPY in the field note book.

The forms and methods of notekeeping are different for various types of survey work. For most surveying a standard notebook has been designed which has the left-hand page divided into six columns and the right-hand page divided into small rectangles with a vertical red line in the middle. Information recorded in field notes are generally classified into three parts: (1) numerical values, (2) sketches and (3) explanatory notes.

6. Numerical values are tabulated records of all measurements. Specific instructions regarding these are as follows:

a. Make large plain figures.

b. Never write one figure on top of another.

c. Avoid trying to change one figure into another.

d. Erasing is prohibited. Draw a line through incorrect value and write correct value directly above.

7. Sketches are graphic records of boundary outlines, relative locations, topographic features or any diagrams needed to further clarify the tabulated numerical values. Specifically:

a. They are rarely drawn to scale. It may be necessary to exaggerate certain portions of the sketch for purpose of clarity.

b. Use a straight edge (6-inch celluloid protractor).

c. The red line in the center of the right-hand page may be used to represent the route of travel on a traverse.

d. Make sketches large, open, and clear.

8. Explanatory notes clarify the numerical values and sketches that might otherwise be misunderstood. Such notes are always printed using some standard lettering style. In all cases one should ask himself if the numerical values and the sketch require additional explanation for easy interpretation. The following explanatory notes are usually included in every set of field notes:

a. Title of project or problem.

b. Its location.

c. Names of the survey party.

d. Duties of each member of the party.

e. Equipment used (with identifying numbers, if any).

f. The date.

g. The weather, because weather conditions govern to some extent the accuracy of the survey.

9. Abbreviations. Some of the common abbreviations and symbols used in field notes are listed as follows:

- *Sta.* station
- *H.D.* horizontal distance
- *D.E* vertical distance or difference in elevation
- *Elev.* elevation
- ∠ angle
- *Defl* ∠ deflection angle
- *B.M.* bench mark
- *T.P.* turning point
- $\overline{\wedge}$ transit or level
- *Com.* compass
- *H.C.* head chainman
- *R.C.* rear chainman
- *H.F.* head flagman

Abbreviations (cont'd)

Vert. ∠	vertical angle	R.F	rear flagman
Int ∠	interior angle	℄	center line
Az.	azimuth	Sec Cor	section corner
Br.	bearing	¼ Sec. Cor.	1/4 section corner
Mag. Br.	magnetic bearing	Tp.	township
Calc. Br.	calculated bearing	Rn	range
Mag. Decl.	magnetic declination	W.M.	Willamette meridian
F.S.	foresight	⊙	transit station
B.S.	backsight	△	triangulation station
H.I.	height of instrument		

10. Sample field notes. An example of one method of keeping field notes is illustrated in figure 1. Notice that in describing the location of station A, the station itself is described as well as its immediate and general location. Anyone not familiar with the area or the survey could locate the starting station and by following the tabulated distances and directions, he could then retrace each succeeding line.

It is optional with the notekeeper whether his notes read from the top of the page down or from the bottom up. Usually in mapping, the notes read from the bottom of the page up. In this way, the notes and corresponding sketch are always oriented with the direction of travel.

	BOUNDARY TRAVERSE of CAMP BALDY				
STA	HOR DIST	FS BRNG	BS BRNG	INT ANGLE	CORRECT BRNG
A				100°00'	
	500.0	S18°00'W	N20°00'E		S20°00'W
E				100°00'	
	1102.7	N77°00'W	S82°00'E		N80°00'W
D				128°00'	
	375.5	N30°00'W	S25°00'E		N28°00'W
C				97°00'	
	789.0	N55°00'E	S53°00'W		N55°00'E
B				115°00'	
	922.9	S60°00'E	N60°00'W		S60°00'E
A		TOTAL		540°00'	
					CHECK
			$(n-2)180$	$=540°$	

Figure 1. Sample note form.

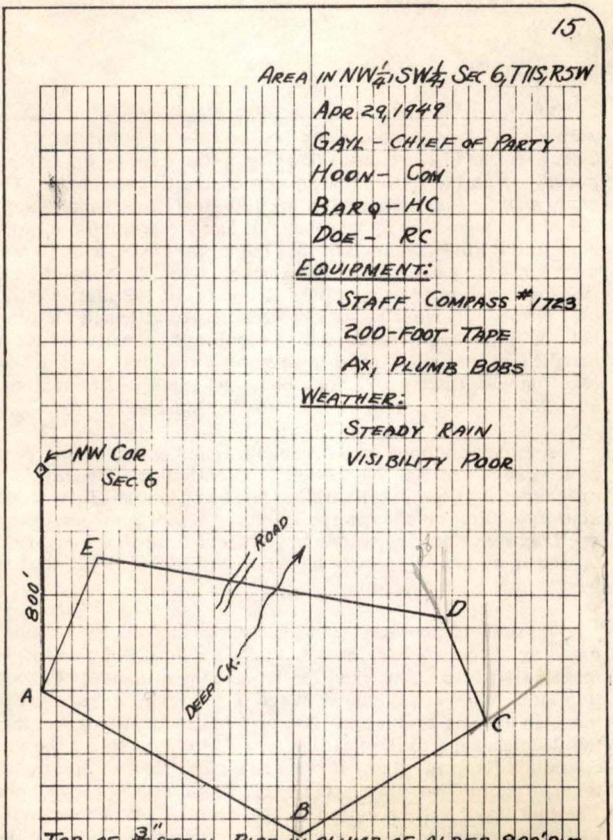


Figure 1. (cont) Sample note form.

CHAPTER II. DIRECT MEASUREMENT OF HORIZONTAL DISTANCE

Section I. The Steel Tape.

11. Units of measurement. The measurement of distance with a steel tape is commonly referred to as "chaining". This term has been handed down from the days of the early surveyors in the United States who used a Gunter chain. This chain was 66 feet long containing 100 steel-wire links, each .66 of a foot or 7.92 inches long. It had a convenient relationship to the mile and acre in that there were 80 chains to the mile and 10 square chains in an acre. Each distance of 25 links was referred to as a pole (1 rod or 16 1/2 feet). This unit of measurement is still in wide usage, although the origi nal chain has been replaced by a steel tape, usually two chains or 132 feet long. Attached to this is a "trailer" used in conjunction with the topographic abney and explained in section 68. The present Gunter tape is now called a surveyor's tape.

Another common unit of measurement in surveying is the foot. There are 100 , 200- and 300-foot tapes available, graduated into even feet with the first and/or last foot graduated into 10ths or sometimes 100ths of a foot in order to measure fractional distances. At the present time this tape, referred to as the engineer's tape, is used more widely than the surveyor's (Gunter) tape.

A frequent misunderstanding arises through the double meaning of the word, "chain". It means a unit of measurement as well as a tool used for measuring distance. Through this ambiguous and common usage of the term, errors are made in solving problems. Because the student will run into the double usage in the field, it is well for him to get the two meanings fixed in mind. However, for the sake of clarity, the term, "chain", will hereafter refer to the unit of measurement. The tool itself will be called a tape, and the act of measuring will be referred to as either "taping" or "chaining". In the latter case, "chaining" is most commonly used. There should be no question as to its meaning.

A third system of measurement, the metric system, has definite merits because of its simplicity. It is used in Europe and other foreign countries. It would be very difficult

to adapt here since the entire intricate public land survey system of the United States is based on the two foregoing units of measurement.

12. <u>Description of steel tapes and auxiliary equipment.</u> Engineer's tapes vary as to thickness, width, and length, depending upon the conditions affecting their use. They are graduated for measuring fractional distances in one or the other of two ways as illustrated in figure 2.

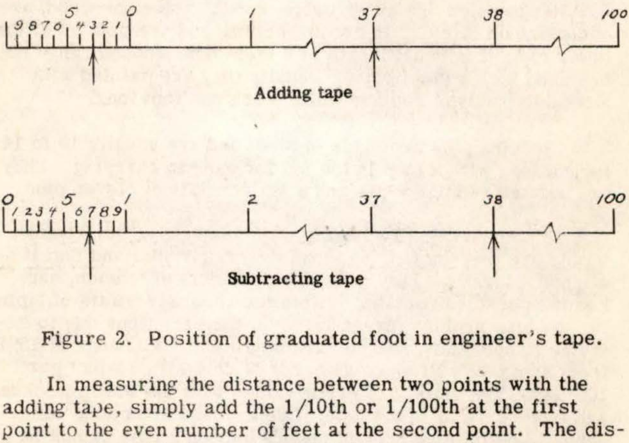


Figure 2. Position of graduated foot in engineer's tape.

In measuring the distance between two points with the adding tape, simply add the 1/10th or 1/100th at the first point to the even number of feet at the second point. The distance indicated in figure 2 is 37.3 feet. With the subtracting tape the 10ths or 100ths are subtracted from the even foot. In figure 2 the distance is again 37.3 feet (38 - .7). The adding tape is the most desirable. Due to its simplicity of use, it is less likely to be subject to error. It behooves the chain man to examine each tape thoroughly before using it and determine whether he is to add or subtract fractional numbers. Sometimes a graduated foot is also conveniently located at the end of the tape.

The surveyor's tape is graduated into 100 even links, each

.66 of a foot long. There is no further subdivision, although it is possible to interpolate to the nearest 1/10th of a link. Usually this is not done, as good results may be had by taking measurements consistently to the nearest link.

Auxiliary equipment sometimes used with steel tape includes plumb bobs for marking points on the ground when the tape must be held higher than the ground, range poles for indicating the position of points or the direction of lines, and chaining pins for marking the ends of the tape during the process of chaining between two points more than a tape length apart.

Range poles are constructed of either steel or wood, are octagonal or circular in cross-section, and are pointed at the lower end. The usual length is 8 feet. The wooden range poles are shod with a steel point. Usually they are painted with alternate bands of red and white, each one foot long.

Chaining pins are made of steel and are usually 10 to 14 inches long with a loop in the top for ease in carrying. They are painted red and white and a set consists of eleven pins.

13. Accuracy. Two basic requirements of horizontal taping are that the tape be absolutely horizontal and that it be aligned laterally. This done, the problems of tension, sag, and temperature remain. Within the accuracy limits of taping for the less precise forest surveys, the variations due to extreme temperature changes are negligible. A change of 15°F. from standard will make an error of only .01 of a foot per 100 feet. The amount of error varies with the width, thickness and type of metal in the tape. Due to these structural differences, a definite number of pounds pull on a tape cannot be set. The keynote then is to be consistent in tensioning. A constant pull of 20 - 30 pounds on the ends of the tape will eliminate error from too much sag, and if the tension is not right it will at least be consistent and thus introduce a uniform error which can be corrected by accepted methods.

Careful taping of horizontal distances should result in an accuracy of about 1/5000.

14. Correcting for non-standard tapes. It is not uncommon to find a steel tape of non-standard length,

particularly those well-used tapes which may be slightly stretched. Distances measured with these tapes must be corrected accordingly. In measuring the distance between two points, a long tape gives the distance too short, and a short tape gives the distance too long, while in laying out a line of given length, the errors are just reversed. Because the problem of correcting for these non-standard tapes is confusing to the student, the following proportional formula will be useful:

Let S equal the standard length of the tape,

T equal its true length,

L equal the true length of the line, and

M equal the measured length of the line.

Then $\frac{T}{S}$ is the length of the tape in terms of standard,

and $L = \frac{T}{S} M$. Knowing 3 of the unknowns, the 4th can be readily found.

15. Care of steel tapes. The steel tape is easily broken when treated carelessly. The chief danger is in pulling on it when it is looped or kinked. Avoid jerking the tape, stepping on it, allowing vehicles to pass over it, and bending it around sharp corners. Wipe it dry before putting away. If it is to be stored for any length of time, other than overnight, spread a light coat of oil over it. The steel tape when treated with care will last a lifetime.

16. Field procedure. a. Throwing and coiling the tape. Prior to taking a tape into the field the student should master the technique of "throwing" the tape, i.e., converting it from the figure eight in which it was coiled to the compact circle for ease in carrying, and he should also learn how to coil and uncoil the tape. These two operations are most easily mastered by actual practice.

There are several ways to coil a tape. One practical method is as follows: Take the zero end, tabs facing up, in the left hand and turn your back to the tape with your left hand across the body. The tape is then strung out behind past your

right side. With the right hand reach back along the tape to a division tab at a good arm's length and without turning the tape over bring that tab up and lay it face up on the first tab. This is repeated until the entire length is coiled. The tape is uncoiled in exactly the same technique, laying off instead of on. With practice, one need not look at the tabs to make sure of the distance each time. He becomes familiar with his reach and will be able to look and walk ahead while coiling or uncoiling the tape.

Note that the tape was coiled starting with the zero end. Likewise, when it is uncoiled by the head chainman, he will finish with the zero end in his hand. The head chainman always stays ahead with the zero end of the tape. He is the one charged with the reading of fractional units off the graduated foot.

b. Chaining. The head chainman walks out along the line until the rear chainman halts him with the command, "Chain!" The rear chainman then lines in the head chainman both horizontally and vertically. Vertical alignment is sometimes accomplished with a Locke hand level containing a level bubble and a sighting line which must coincide to give a horizontal line. While the level is not used continually in practice, it is wise to use it when learning to tape, as the conception of a horizontal line off a slope is difficult to acquire and is a constant source of error.

Horizontal and vertical alignment assured by the rear chainman, he sings out, "Stick". The head chainman pulls the tape taut and sticks his chaining pin into the ground, replying when done, "Stuck". The distance is then checked and recorded before the chainmen measure the next distance.

While the head chainman is equipped with chaining pins, it is usually an unnecessary encumberment for the forest surveyor. Since stations are frequently set on steep topography, a full complement of pins is seldom used. The head chainman, who must carry an ax, cuts his chaining pins as he goes.

Because the bulk of the taping will not be done on the flat, it is necessary to have some means of marking a point on the slope which falls directly under a mark on a tape held horizontally. It has already been stated that the tape must be level to measure horizontal distance direct. On slopes, therefore,

one end of the tape will be off the ground, and the plumb bob, hanging vertically, is used to mark the point on the ground. Taping uphill requires the rear chainman to hold his end of the tape up; downhill, vice versa. On steeper slopes it will be necessary to "break chain", that is to take less than the full length of the tape as slope demands in order that the tape will always remain level.

17. Field notes. Convenient note forms for taping are illustrated in figure 3. Notice that the figures in the station column accomplish two functions. They not only identify the station itself, but they show its accumulated distance from the starting station. In place of these numbers, letters are often used in small closed figures where there is no need to know the accumulated distance to any station.

STA	DIST	STA	DIST	STA	DIST
3+03.6		4.60		D	
	51.1		88		51.1
2+52.5		3.72		C	
	152.5		2.72		152.5
1+00.0		1.00		B	
	100.0		1.00		100.0
0+00.0		0.00		A	
Engineer's tape		**Surveyor's tape**		**Lettered stations**	

Figure 3. Note forms for taping.

As noted, distances in surveyor's chains are recorded as chains and hundredths, the latter representing the number of links. Care must be used in recording. For example, a common error is to record a distance of 3 chains 7 links as 3.70 instead of 3.07.

18. Sources of error. Some common mistakes in reading and recording and other sources of error in taping are as follows:

a. Imperfect alignment.

b. Tape not horizontal.

c. Variable tension.

d. Tape bent over or around brush.

e. Too much sag.

f. Adding or dropping a full tape length.

g. In measuring fractional feet, adding or dropping a foot.

h. Wrong points taken for 0 or 100 foot marks.

i. Reading wrong numbers (89 for 68 or 6 for 9).

j. Calling incorrect numbers to notekeeper (53.0 meaning 50.3 for example).

k. Tape not standard length.

l. Extreme temperature variations.

19. Measuring inaccessible lines. When prolonging a straight line across forested areas, one often runs into barriers which must be sidestepped. Two methods of measuring these inaccessible distances with a tape only are illustrated in figure 4.

These two methods are facilitated when used with a compass. The compass is necessary if one must traverse around a barrier or if it is desired to construct a right triangle and solve for the side which is inaccessible.

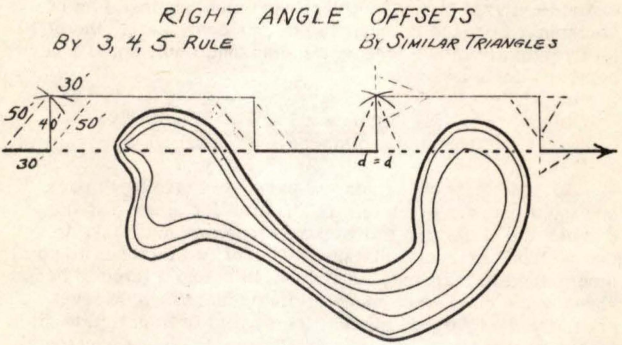


Figure 4. Measuring inaccessible lines with tape only.

Section II. Measurement by Pacing.

20. Definition and use. A pace is a measurement of horizontal distance. Regardless of the slope it is always recorded in terms of horizontal distance. It is most handily used in retracing lines for locating public land subdivision corners. Timber cruisers use the pace extensively, and for the construction of an inexpensive less precise type of map the pace used with the hand compass is often quite satisfactory.

21. Units of measurement. Since no one but the individual concerned knows the length of his respective pace, paces as such are never recorded in the field notebook as a unit of measurement. They are always converted to some standard unit, such as to feet or to chains, before recording in the notebook.

22. Per cent of slope. It is advisable at this point to define per cent of slope, a term to be used frequently

hereafter. It is common practice to give the grade of a slope in terms of per cent. This is not to be confused with the "vertical angle", the angle between the horizontal plane and the line of sight along a slope. Per cent of slope is the number of feet rise vertically per 100 feet on the horizontal. For example, a rise of one foot vertically in a hundred feet of horizontal distance is equal to one per cent, and a rise of 10 feet vertically in 200 feet on the horizontal will equal 5 per cent. By formula:

$$\% \text{ slope} = \frac{\text{vertical distance} \times 100}{\text{horizontal distance}} = \frac{10 \times 100}{200} = 5\%$$

23. Methods of learning to pace. In learning to pace, one must become proficient in allowing for slope, for the steeper the slope, the more extra steps one must take to get the desired horizontal distance. One of two methods is commonly used in learning; the first is to set up a table of paces showing the number of paces an individual takes on level ground and on various slopes; the second is to estimate distances by eye where the ground changes from the horizontal. In the latter, the pacer must have a good mental picture of the length of his horizontal pace so that it may be applied in steep and brushy terrain. Usually it is wise for the beginner to fill out the table of paces for practice, and as he becomes more proficient he will develop the second method. Finally, when he has had ample practice, he is able to apply a combination of the two methods, using the pacing table on long, uniform, gradually-changing slopes, and applying the ocular estimate for brushy, abruptly-changing slopes.

24. The pacing table. Figure 5 shows the form to use for construction of a pacing table. Courses are laid out for distances of 1 tally each (5 chains, or 330 feet).

		AVE. No. of PACES UPHILL				AVE No. of PACES DOWNHILL			
DIST	ZERO COURSE	10%	20%	30%	40%	10%	20%	30%	40%
330′									
"									
"									
"									
"									
MEAN									
AVE. LENGTH OF DOUBLE PACE ON LEVEL GROUND									
No. of PACES PER CHAIN									
No. of PACES PER 100 FEET									

Figure 5. The pacing table.

Each course is traversed five times, and an average is taken of the number of paces. Any count differing from the others by three paces or more is thrown out, and the course is traversed again.

When the table is completed, the pacer has his average number of paces per tally on the level. In addition to this basic information, he knows how many more paces he takes on various slopes than he does on the level. He is also able to compute the length of his double pace (it is optional whether the pacer uses double or single paces, but the double pace is usually preferred). To make the table more useful, he should convert his paces per tally to paces per chain and to paces per hundred feet.

This training aid is by no means infallible, for one cannot become proficient in pacing without constant practice. Slopes do not fall at even per cents for uniform 5-chain distances, but knowing the number of extra paces required on these slopes, one has a better concept of the effect of slope on his pace, and he is able to adjust accordingly.

The pacing table should be copied into the field notebook where it will serve as a useful reference whenever pacing is required. Because the pace is merely another tool for measuring distance, the field notes for pacing will follow the same form as field notes for taping.

25. Cautions and sources of error. A constant rate of travel at a free and natural walking gait is the key to successful pacing. Consistency is developed only through continued practice, together with alertness on the part of the individual. Errors usually develop through one or more of the following:

a. A tendency to stretch out in the morning at a rate one is unable to maintain throughout the day.

b. Inaccurate recording.

c. Varied physical condition of the pacer.

d. Amount of brush.

e. Change in type of shoe.

f. Condition of soil and weather.

g. Walking with someone else. No two people will have exactly the same pace, and one is inclined to fall into step with the other person.

Since the natural tendency is to lose rather than gain accuracy, one should take advantage of every opportunity to check his pace over measured distances.

26. Auxiliary equipment. Two useful tools will improve the pacer's work. The first is the "tallywhacker", a counting device carried in the hand to help keep track of the distance. Pacers use this device to record distance by tallies, chains, or 100 foot lengths and it may also be used to count each pace between recordings to the field notebook. The other aid is a stick or compass staff on which is marked the length of one pace. This is particularly handy when going up a steep hill or through heavy brush, when it is desired to visualize the actual pace.

27. Accuracy. As previously stated, accuracy depends primarily on consistency. When one has become proficient at pacing, he should have an accuracy ratio of 1 in 80 or 1 chain in a mile in rough country. To retain this amount of accuracy will require constant practice and checking. For work requiring no more accuracy than 1 in 80, pacing is an inexpensive and rapid method of measuring distance.

Section III. Problems.

1. A line measured with a 100-foot tape is found to be 987.2 feet long. Later the tape is discovered to be .09 foot too long. What is the correct length of the line?

Answer: 988.09

2. With this same tape you are required to lay out a base line 1000 feet long. What distance will you measure to obtain the required distance?

Answer: 999.10

3. A line, measured with a 100 foot tape, is found to be 1008.7 feet long. Later the tape is discovered to be .17 foot too short. What is the correct length of the line?

Answer: 1007.0

P10 4. A base line is known to be 1 tally long. Using extreme care, you measure this line with a 2-chain surveyor's tape, and get 5.22 chains. How much too short or too long is the tape?

Answer: 8 links too short

5. With a subtracting tape a distance was measured and recorded as 72.6 feet. What number was (a) the head chain man holding? (b) the rear chainman?

Answer: (a) 0.4 feet
(b) 73 feet

6. How would you turn a right angle if your only tool was a steel tape?

Answer: Reference figure 4

7. In measuring a line with a 100-foot tape the forward end is held 4 feet too high. What is the error in one tape length?

Answer: .045 feet

8. A distance measured along a slope with a 300-foot tape was found to be 287.94 feet. If the difference of the level of the ends of the tape was 16.2 feet, what was the horizontal distance?

Answer: 287.5 feet

9. A distance of 200 feet is measured along a 10 per cent slope. What is (a) the horizontal distance? (b) The difference in elevation between the two points?

Answer: (a) 199.0 feet
(b) 19.9 feet

10. The distance along a slope is 120 feet. The horizontal distance is 118.7 feet. What is (a) the per cent slope? (b) the difference in elevation?

Answer: (a) 15% (b) 17.8 feet

11. The horizontal distance is 296.7 feet; the difference in elevation is 44.5 feet. What is (a) the per cent slope? (b) the vertical angle? (c) the slope distance?

Answer: (a) 15% (b) 8^{o} 32'
(c) 300.0 feet

12. The difference in elevation is 62.7 feet between two points along a 35 per cent slope. What is (a) the horizontal distance? (b) the slope distance? (c) the vertical angle?

Answer: (a) 179.3 feet
(b) 190 feet (c) 19^{o} 17'

13. A rectangular lot 60 x 80 feet is to be surveyed with a 100-foot tape which is .15 of a foot too long. How long is the diagonal by this tape?

Answer: 99.85 feet

CHAPTER III. MEASUREMENT OF DIRECTION

Section I. General

28. Angular relationships. The angle which a line makes with some reference line establishes the direction of that line. The reference line is usually a true North-South line called a meridian. If the reference line is that indicated by a magnetized compass needle, it is referred to as a magnetic meridian.

Units of measurement used by the forest surveyor for determining angles and directions are degrees, minutes, and seconds. Compass work eliminates the latter division, since most of the compass circles are graduated in half degrees only.

Certain angular relationships should be fixed in mind before examining the compass. These relationships are based on the intermingled use of azimuth and bearing. Because there are instruments graduated in either one or both of these units, it is often necessary to convert one to the other.

The bearing is the acute angle which a line makes with the meridian, the true or magnetic North-South line. Thus, bearings are measured from North or South to the East or West, dividing the circle into quadrants equal to 90 degrees each. No bearing is therefore greater than 90 degrees. Figure 6 illustrates directions of lines in terms of bearings.

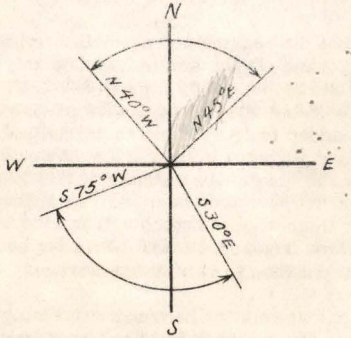


Figure 6. Bearings.

Azimuth is the clockwise angle measured from North or South, 0 to 360 degrees. In forestry work it is usually measured from North and will be so treated herein. Azimuths are readily converted to or from bearings if one will draw a quadrant indicating the cardinal directions and the direction of the line given. Northeast bearings are azimuths of 0 to 90 degrees; southeast bearings are azimuths of 90 to 180 degrees; southwest bearings are azimuths of 180 to 270 degrees; and northwest bearings are azimuths of 270 to 360 degrees. Figure 7 indicates azimuths corresponding to the bearings in figure 6.

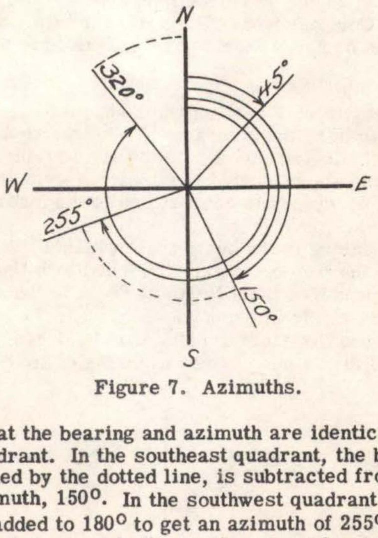


Figure 7. Azimuths.

Notice that the bearing and azimuth are identical in the northeast quadrant. In the southeast quadrant, the bearing, S 30° E, defined by the dotted line, is subtracted from 180° to get the azimuth, 150°. In the southwest quadrant the bearing of 75° is added to 180° to get an azimuth of 255°. Like wise, the dotted segment in the northwest quadrant is sub tracted from 360° to get the azimuth of that line. While rules for each quadrant have thus been indicated, there is no need to remember them when a sketch will suffice to clarify every angular situation beyond all doubt. It is far better to think each problem out than to rely on memory.

The graphical solution becomes extremely valuable where angles between two or more bearings or azimuths are required.

To solve these relationships, it is often desirable to employ the back bearing or back azimuth. This is the reverse of the forward direction, a difference of 180 degrees. Back bearings retain the same number, but the letters designating the quadrant are opposite. For example, the back bearing of N 40^o W in figure 6 is S 40^o E. Back azimuths are found by adding or subtracting 180^o from the forward azimuth. The back azimuth of 320^o in figure 7 would be 320 - 180 or 140^o. The back azimuth of 45^o would be 180 + 45 or 225^o. Back azimuth or bearing is sometimes called backsight azimuth or backsight bearing respectively. Forward directions likewise are designated frequently as foresight bearings or foresight azimuths. Unless otherwise stated, the terms azimuth or bearing are understood to mean the forward direction of the line, and it is unnecessary to define them further.

The most common angles used in forest surveying are the interior angle and the deflection angle. The former is the inside angle between two lines in a closed figure [in a closed polygon, if $\underline{n}$ is the number of sides, the sum of the interior angles is $(\underline{n} - 2) \times 180^o$].

The deflection angle is that angle that is deflected off a straight line prolonged through the occupied station. Deflection angles must be designated: "left" or "right". Figure 8 illustrates the relationship of these two kinds of angles.

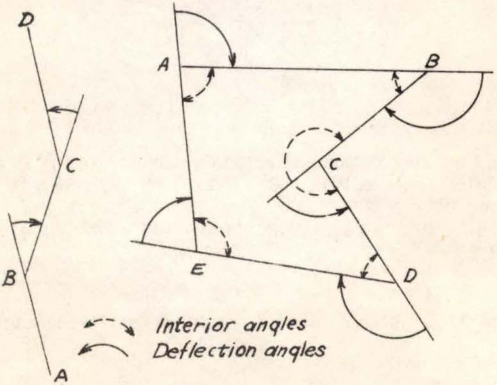
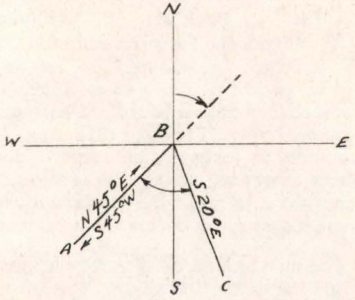
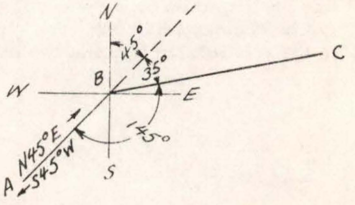


Figure 8. Deflection and interior angles.

The problems usually involved with angles and directions consist of finding the angle between lines of known direction or of determining the direction of a line when the angle between it and another line of established bearing is known. Some of these are solved by sketch in figure 9.



Find angle ABC by superimposing quadrant over figure as shown and using back bearing of AB. Angle ABC = 45 + 20 = 65°. Deflection angle = 180 - 65 = 115°.



To find bearing BC, superimpose quadrant over B as shown. Deflection angle at B is 180 - 145 = 35°. 45 + 35 = 80°. Bearing BC = N 80° E. Or, with the back bearing of AB, 145 - 45 = 100° = angle SBC. 180 - 100 = 80°. Bearing BC = N 80° E.

Figure 9. Graphic solution to problems involving angles and directions.

29. Magnetic declination. As indicated in article 28, the direction defined by the magnetized needle of a compass and that established by true geographic meridians is seldom the same. The angle between a line of true direction and a line of magnetic direction is called the magnetic declination. It is the amount that the magnetic meridian varies from true meridian. If the north end of the compass needle points to the east of the true meridian, the declination is said to be east; if it points to the west, the declination is said to be west. The declination may be estimated with sufficient accuracy for most purposes from an isogonic chart of the United States, published by the United States Coast and Geodetic Survey (figure 10). The chart shows isogonic lines, or lines of equal magnetic declination for the date of issue. Also it indicates the rate of change in magnetic declination from year to year.

In addition to this rate of change of several degrees over a long period of time, the declination makes an additional and separate swing annually and even daily, but the amount is negligible for compass work. There are also irregular variations usually due to magnetic storms. They may amount to a degree or more at high latitudes.

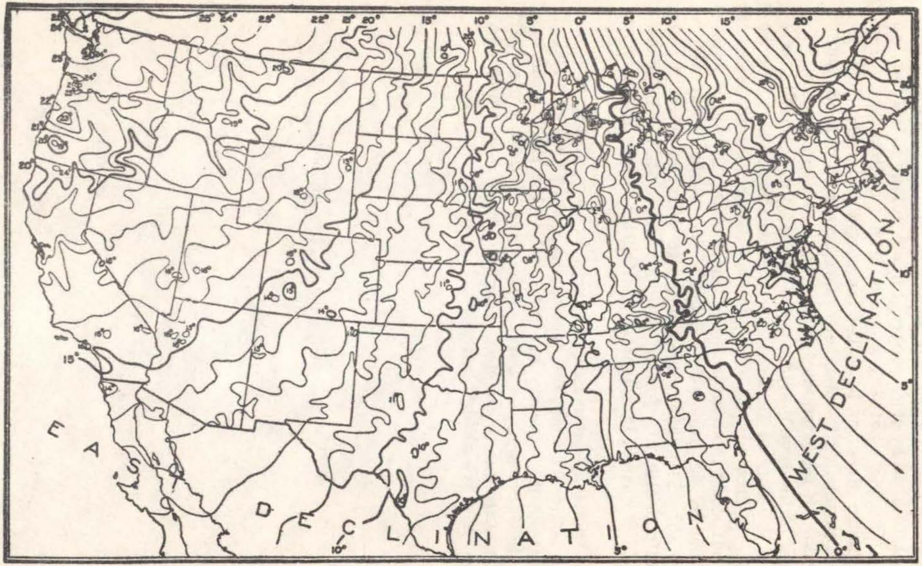


Figure 10. Isogonic chart of the United States, showing lines of equal magnetic declination.

In some areas it will be found that the declination taken from the isogonic chart is not sufficiently exact. If a true North-South line is established, the mean declination of the needle for that locality can be determined by compass observations extending over a period of time.

Occasionally one is faced with the problem of converting from magnetic to true direction or vice versa. This will be simplified again if a sketch is used to portray the situation. For example, the declination is 20° 30' East. You have a magnetic bearing of S 5° 30' W and desire to know the true bearing of that line. To solve, set up the quadrant representing the true cardinal directions and superimpose in correct relationship the magnetic quadrant. The true bearing by inspection becomes S 26° 00' W. See figure 11. By using the same approach, true directions may be converted to magnetic directions.

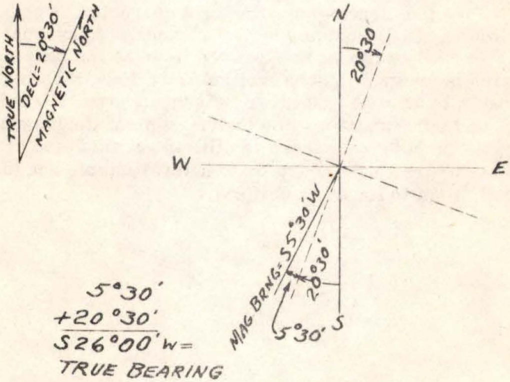


Figure 11. Conversion of magnetic direction to true direction.

30. Local attraction. A common phenomenon in many mountainous areas is that called local attraction. The lines of magnetic force are frequently altered by objects of iron or steel, iron ore deposits, and electric lines. Usually it is possible to correct for this condition.

If local attraction exists at a station in a traverse and not at its adjacent station, or at a greater or lesser degree at its adjacent station, the foresight and backsight bearings of a line between these two stations will not agree numerically. However, both the forward and back bearings taken from one of the stations will be affected by the same amount, because the needle does not change direction as long as the compass remains at a specific station. Therefore, the angle at that station between the affected lines is the true angle regardless of the amount of local attraction. It follows, therefore, that all the angles in the traverse may be computed and by using these angles, the bearings may be calculated through the affected area from the closest unaffected line showing agreement in back and forward bearings. Figure 12 illustrates this method of adjusting for local attraction.

It is obvious that all personal error must first be eliminated before this process may be used correctly. Local attraction is usually blamed for all manners of personal error. When every effort has been expended to make the bearings agree and the work has been meticulously done, then it is reasonable to assume that other influences have affected the needle, and adjustment may be undertaken. If the bearings and angles do not close, there is still an accumulated error likely due to personal failure or to natural minute accumulations, but not to local attraction.

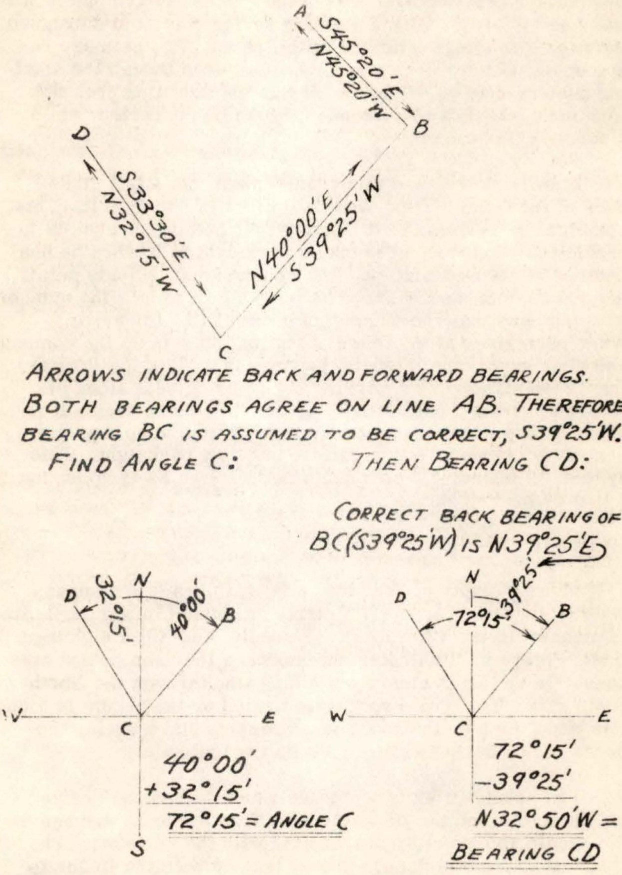


Figure 12. Correcting for local attraction.

Local attraction becomes quite troublesome when prolonging a straight line across a section of land when strip mapping or cruising. Its effects may be neatly avoided if one will use his compass as a sighting device only, and disregard the needle readings after the initial setup. The primary requirement is to prolong a straight line, even though the starting bearing may be defective. If this straight line does not terminate where it was intended, it can be corrected, while a crooked line cannot.

In order to execute this requirement, set a tall stake back of the intial station, and fix a piece of paper to it. This combination is known as a "butterfly", and its purpose is to enable the compassman to take a backsight to it when he has arrived at his next station. The compassman selects points, natural objects, as far ahead as possible to reduce the number of setups and thus the number of possibilities for error. When he arrives at the forward station, he sets up the compass and standing at arm's length, he lines it up with the "butterfly", then sights ahead, picking out other objects along his line, and setting "butterflies" behind him. Sometimes it is unnecessary to set the butterfly if one can pick up a prominent object behind the compass to use as a backsight. This system of extending a compass line is known as "prolonging a line by backsights".

Section II. The Hand Compass.

31. Description. The essential features of a compass used in surveying are: (1) a circle graduated in angular units of measurement, (2) a magnetic needle, and (3) a sighting line. Figure 13 illustrates one model of the hand or box compass. On the lid is etched a sighting line through the North-South axis. The true direction indicated by the needle is along this line. Also on the cover is a township plat showing the order of numbering sections within the township.

The needle lifter is a plunger which raises the needle off its pivot when the lid is closed. This prevents damage to the needle and jewel when traveling with the compass. The lifter is also convenient to use by tapping with the finger to stop the swing of the needle, thus settling it more quickly.

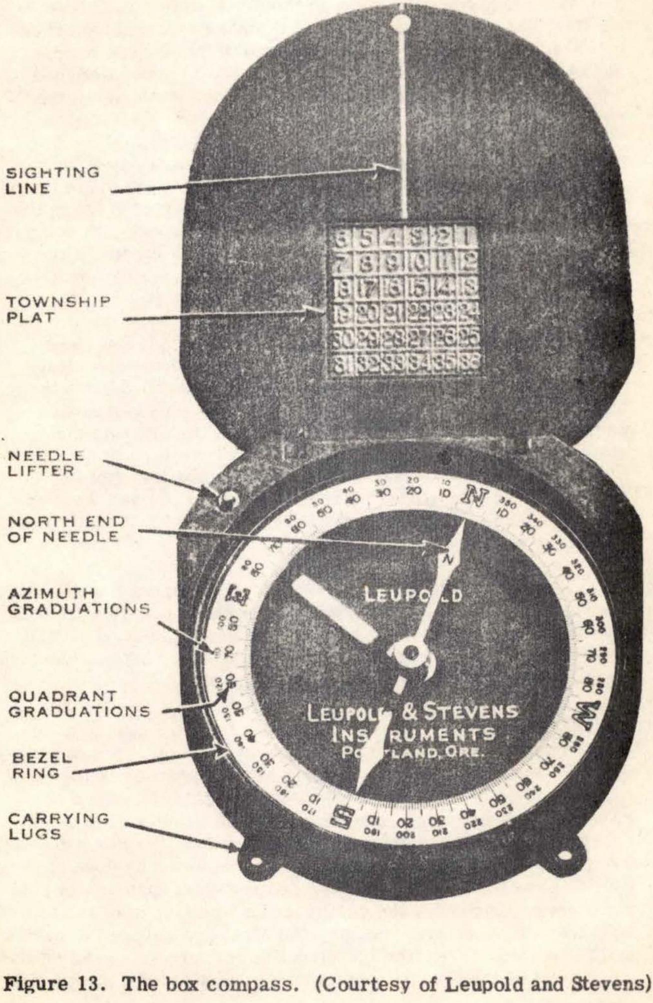


Figure 13. The box compass. (Courtesy of Leupold and Stevens)

The needle itself is of tempered steel, magnetized, and supported by a jewel bearing on the pivot so that it is free to rotate. The north-seeking end of the needle, usually marked by an arrow, points to the north magnetic pole. The needle also tends to dip vertically. Vertical dip is prevented by a small adjustable wire counterweight on the south end of the needle.

Compass dials are graduated in single degrees or in degrees and half degrees. The numbers indicate the angle from the meridian (the North-South line) to due East or West in the bearing or quadrant compass. The dial of the azimuth compass is numbered from North clockwise around the circle. Com passes may be graduated for reading either bearings or azimuths or both.

On the compass dial the cardinal directions, East and West, are reversed to enable the user to read the direction (in which the sighting line is pointed) directly off the North end of the needle. For example, hold the compass so that the north end of the needle points to North on the dial and the sighting line also thus indicates North. Then turn the compass to the right in an easterly direction. The north end of the needle will read northeast directions since East and West are reversed on the dial. If they were not reversed, it would read incorrectly, i.e., northwest directions.

The dial is also adjustable so that the magnetic declination for any area may be set off and thus make it possible to read true directions off the north end of the needle instead of magnetic directions. To adjust the dial, the bezel ring is removed, freeing the glass cover and exposing the dial.

32. Accuracy. Accurate work with the hand compass depends upon: (1) its construction and (2) the user. A compass having a long sensitive needle with narrow points resting close to the graduated circle will give best results. The hand compass, with an accuracy ratio of 1 to 80, is usually used when pacing. The most experienced pacer will find the compass well within the accuracy limits of his pace, provided he does careful compass work as well. The greatest discrepancies in compass work are usually the result of the compassman failing to hold the compass level, reading the direction before the needle has fully settled, reading the direction incorrectly, reading the wrong end of the needle, and moving forward to the wrong object.

33. Adjustment. In addition to the points mentioned in article 32, the hand compass must be in proper adjustment to give accurate results. Assuming that the compass was properly constructed, the needle must be straight, sufficiently magnetized and balanced; the pivot point must be sharp; and the point of the pivot must be centered in the graduated circle.

If the difference between the two end readings of the needle varies at different positions, the pivot is bent. Straighten the pivot until the difference between the two end readings is constant at various positions. If this adjusted difference is not 180° the needle is bent. The needle must be straightened so that when it is balanced and level there is exactly 180° difference between the North and South ends.

If the needle dips, slide the wire counterbalance to a position so that the needle sets level.

To remagnetize the needle, pass the south end of a magnet from the center of the needle to the tip of the north end, and in a like manner, the opposite end of the magnet should be passed over the south end of the needle. Each pass should describe an eight-inch circle. About 35 passes are sufficient to reactivate the needle.

If the pivot is blunt, remove it from the box, mount it on a stick, and twirl it against a fine whetstone at an angle of about 30°. Then polish it off by rubbing it against soft, clean leather. This adjustment is best left to a jeweler if possible, as carelessness may prevent further accurate work.

34. Care of the hand compass. A compass, properly treated, will last a lifetime as will other surveying instruments. A few simple precautions should become habit. The compass lid should be closed when the compass is not in use, thus raising the needle off the pivot and preventing damage to the jewel or wear on the pivot. The compass should be handled gently. Avoid dropping or vigorous shaking. Treat it as you would your watch. Dry it off thoroughly if it has been used in wet weather, and finally, carry it in a buttoned pocket or case if available. Although there are carrying lugs for a cord to be hung around the neck, additional precaution should be taken in pocketing the compass while moving through the brush.

35. Field procedure. The method of using the hand compass is simple and once one has gained sufficient practice, he will find it a rapid method of traversing for less precise surveying work. Hold the compass level in both hands just above the belt with the sighting line pointing away from the body and at right angles to the plane of the body. It will help to steady the compass if both arms are held against the body. Turn the whole body until the north end of the needle points to the direction in which it is desired to travel. Look up along the sighting line, pick out some mark on the line ahead and "follow your nose". Literally, this is what is done. If it is necessary to know the direction to a certain object, as in traversing the perimeter of a fire preparatory to mapping the burned area, hold the compass as suggested and turn the body until the sighting line points to the desired direction. Then read off the direction at the north end of the needle.

36. Field notes. In addition to columns designating station and horizontal distance, the field note form for the hand compass should have a third column to record the direction travelled in terms of bearings or azimuths. Sometimes a fourth column is reserved for interior angles or deflection angles between the observed directions.

37. Sources of error. Some sources of error were listed in article 32. These with several others are summarized as follows:

a. failing to hold the compass level,

b. reading the direction before the needle has fully settled,

c. reading the direction incorrectly,

d. reading the wrong end of the needle,

e. moving forward to the wrong object,

f. failing to note if the compass is in adjustment,

g. failing to recognize the importance of taking back sights at every setup to eliminate personal error and that introduced by local attraction, and

h. working too close to wire fences and other objects containing iron.

38. Auxiliary uses of the hand compass. The hand compass may be used as a straight edge in orienting maps and determining directions on maps after they are oriented. Either side of the compass is parallel to the sighting line, thus, if one side is made to coincide with the direction arrow on the map, and the map is turned until the north end of the needle reads that direction, usually north, the map is then oriented. After it is oriented, the compass can be lined up with any line on the map of unknown direction, and by reading the north end of the needle, the bearing or azimuth of the line may be determined. Angles between any two lines may likewise be found if the directions are first established.

The declination adjustment is often used in the field to correct errors in lines run between United States Public Land Monuments or between other public or private markers. An angle of one degree subtends a distance at one mile of approximately 92 feet. Knowing this relationship, one can prolong a straight line from one monument to another, and if he missed the second monument by 90 feet, he would correct the declination by 1 degree, start at the second monument, and return to the first blazing the line and setting permanent markers if necessary as he progressed. If his work was carefully done on both lines, he would end up at the original monument at the end of the second line.

The danger lies in making the declination adjustment in the wrong direction. This may be avoided if one will remember the following rule of thumb: In western United States, an increase in declination will throw the line to the left, while a decrease in declination will throw the line to the right. For example, suppose that in running a line from the southeast corner of a section to the northeast corner, a distance of one mile due North, you finish 138 feet to the right. That means that you were not using enough declination. $\frac{138}{92} = 1\ 1/2$ degrees too far to the right. Therefore, by increasing the declination by 1 1/2 degrees, you would throw your second line 138 feet to the left, and if care were taken to prolong the straight line, it should connect the two corners as desired.

A further use of the declination adjustment is by those experienced compassmen who, after constant checking, have discovered that due to some peculiar trick of their eyes they

are running consistently too far to the left or to the right. After determining this "drift" with a reasonable amount of exactitude, they are able to adjust the declination, thus correcting for the phenomenon and thereafter performing surprisingly accurate work. This operation should not be used by the novice, for the correction is determined only after working over a long period of time. The error of the beginner is as likely to be in one direction as another. All other errors must be eliminated before this one can be determined and measured, a process which of course takes numerous samplings before an average may be found.

Section III. The Staff Compass.

39. Description and auxiliary equipment. The staff com pass surveyor's compass, or forest service compass consists of a compass box as previously described. The sighting line is established by two vertical sighting vanes set at opposite sides of the box on the North-South axis. The rear vane contains a narrow aperature. The front sight contains a vertical hair mounted at the center of a wider opening. The box is fastened rigidly to a vertical spindle which is free to revolve in a conical socket. Below the spindle is a leveling head consisting of an adjustable ball-and-socket joint. The upper portion of the socket is a thumb nut which is tightened until the ball is held securely by friction. The leveling head may be screwed on to a wooden staff (Jacob's staff). The staff may be made with an ordinary hoe handle by cutting off the blade, straightening and sharpening the shank, and fixing the leveling head to the opposite end.

The compass is leveled in one of two ways. There is either a circular level vial ("bull's eye") mounted within the box, or there are two level vials mounted at right angles to each other on opposite corners of the frame just outside the box. The compass is provided with thumb screws for lifting the needle off its pivot and for clamping the vertical spindle. The needle is provided with a wire counterweight, as heretofore described, to counteract the effect of magnetic dip. The compass circle usually is graduated in half degrees from North or South to 90° on the East or West, and bearings may be read to the nearest degree, or estimated to the nearest one half of a degree. The scale is so constructed that the declination may be set off, usually by means of an exterior screw so that it will be unnecessary to remove the glass over the box.

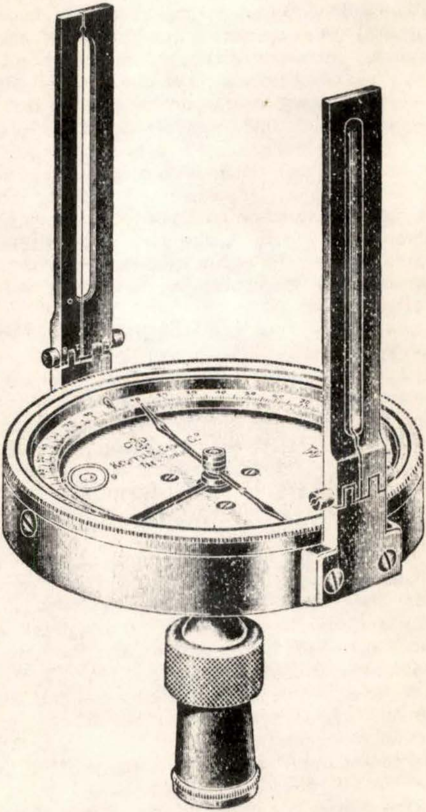


Figure 14. The staff compass. (Courtesy of Keuffel & Esser)

In addition to measuring horizontal directions, some staff compasses are equipped with one or both of two means for measuring angular relationships between the horizontal plane and the vertical line of sight. One method consists of graduating the sighting vanes in terms of per cent so that with the eye held at a fixed zero point on the rear sight a numerical per cent of slope to the object can be read off the front sight. For rough approximations this is convenient and rapid. The other method also allows for reading per cent slope. The socket in the leveling head is notched out so that the spindle with the compass mounted may be tipped 90°, placing the compass box in a vertical plane. Freely suspended from the needle pivot is an arm which reads zero on a per cent scale when the sighting vanes are on the same level. Tilting the line of sight changes the reading since the arm is always hanging vertically. While it is useful to know these uses of the staff compass, they are seldom employed because the abney is considered more accurate for accomplishing the same results.

40. Accuracy. The staff compass is considered more accurate than the box compass, because: it is mounted and steadied in a level position; it has a well-defined sighting line; it contains a larger, more sensitive needle; and it can be read to finer precision than is possible with the compass box. One usually paces when using the hand compass, while the staff compass usually requires a crew of two or more men taping distances and taking more care with angular measurements. The accuracy ration is about 1/300.

41. Adjustment. In addition to the adjustments required for the hand compass, two more are required on the staff compass. The plane of the bubbles must be parallel to the compass plate, and the plane of the sights must be perpendicular to the plane of the bubbles. To make the former adjustment, level the compass and rotate it 180°. If the bubbles are then out of level, correct each tube by one half the movement of each bubble and relevel. Repeat the process until the bubbles remain centered when the compass is rotated. To make the sights perpendicular to the plane of the bubbles, level the instrument and sight to a plumb line hung a short distance away. If the plumb line coincides with the sighting line throughout the length of the latter, the instrument is in adjustment. If not, the sighting leaf must be removed and ground off at the base so that it sets level. Before doing this, however, it

should be determined if the sighting vane itself has been bent in which case straightening it may be sufficient to correct the error.

Any instrument which has been damaged by blows or dropping should be sent to the manufacturer for repair, providing routine adjustments fail to correct the discrepancies. All reputable firms maintain service facilities for their products, and they are better equipped to adjust them than is the average user.

42. Care of the staff compass. The woodsman who treats his equipment with respect will not require the services of the manufacturer. If he will conscientiously observe the following precautions, the life and accuracy of his compass will be prolonged.

a. Avoid blows or dropping.

b. Raise the needle off its pivot when not in use.

c. When placing in case, fold the front sight under the rear sight to protect the vertical hair.

d. Carry the compass in its case, never on the staff.

e. Place compass on the staff after the staff has been set into the ground.

f. Dry compass off thoroughly after using it in wet weather.

43. Field procedure. Surveying with the staff compass usually takes one of two forms: traversing boundaries of irregular distances and directions, or prolonging straight lines through areas, as from one public land monument to another. In the former operation, the compassman is usually the chief of party and may keep notes as well. His chainman and axmen work on the line directly in front of the occupied station. The chainmen are not permitted to go ahead several stations because there are other duties for them in connection with the measurement of direction. They act as flagmen on preceeding and following stations while bearings are being taken, then they commence taping while the compassman is making calculations and preparing to occupy the next station.

This type of organization is used in route location and in laying out curves for truck roads where transit work is not required.

The economic unit for running strips in map construction is a two-man crew, chief of which is the topographer, the man who keeps the notes and constructs the map data as the work progresses. He is also the rear chainman. The compassman in this case is the head chainman, He must learn to prolong a straight line independent of anyone else. He sets his own "butterflies", picks points ahead, and will find that he has plenty of time to make an accurate line because the topographer is the busiest man in the crew. Either man may operate the abney in this organization. The usual procedure is for the men to take the distance and abney reading as soon as the compassman has reached the forward station. The topographer then has the information he needs and the compassman has sufficient time to attend to his line.

In prolonging the line, the compassman must be careful to eliminate local attraction as previously explained. Prolonging the line by backsights is the safest method to use if there is reason to believe that variations exist.

44. Field notes. The field note form for use with the compass in topographic mapping will be explained in articles 67 and 69 under the chapter on the abney level. Figure 15 illustrates a form commonly used for compass traverses. In this case the boundaries of a closed figure are defined. Part of the area is apparently affected by local attraction. The interior angles are first balanced before computing the corrected bearing by the method explained in article 30. Since the least reading on the compass is one half a degree, the entire error if less than one degree is thrown to the station preceeding the shortest side. In compass work there is more chance of error on short shots than on long shots where even a figure of a man is covered by the vertical hair in the front sight. In five setups an error greater than one degree would indicate personal failure and the work should be checked again in the field. When the figure is plotted to scale, it should close if there has been no gross taping error. Its failure to close would require a recheck of the distances. This field method of "adjusting the traverse" will eliminate gross errors. The remaining accidental errors should be within the accuracy requirements of the equipment, so the figure will close and eliminate the need for employing other graphical methods of adjustment.

STAFF COMPASS TRAVERSE

STA	HOR. DIST	FS BRNG	BS BRNG	CORR. BRNG	INT. ANGLE
A					100°00′
	218.0	S60°00′E	N60°00′W	S60°00′E	
B					115°00′
	182.9	N55°00′E	S53°00′W	N55°00′E	
C					97°00′
	199.2	N30°00′W	S25°30′E	N28°00′W	
D					128°00′ ~~128°30′~~
	172.3	N77°00′W	S82°00′E	N80°00′W	
E					100°00′
	210.7	S18°00′W	N20°00′E	S20°00′W	
A				TOTAL	~~540°30′~~ 540°00′
					check

$(5-2)180° = 540°$

Figure 15. Field notes for a closed compass traverse.

45. Sources of error. In addition to those listed in article 37 on the hand compass, the following sources of error are introduced with the staff compass:

a. sighting vane or vertical hair bent out of line,

b. staff not vertical when occupying stations, and

c. needle sticking without knowledge of operator. This can be avoided by slight tapping on the glass before reading. If the needle was stuck it would swing free with light tapping.

Section IV. Areas.

46. Area by trigonometric calculation. Because extremely accurate calculation of area is not practical when using less precise methods of measurement, the various trigonometric methods will not be discussed here. These methods include area by double meridian distance, by double parallel distance, and by coordinates. Most of the standard surveying texts cover these systems thoroughly. If the student desires to calculate the area of a small closed figure surveyed with the compass, one or two additional measurements will often suffice to divide the figure into triangles, trapezoids, and rectangles from which separate areas may be computed and the total area determined by addition.

47. Area by graphical methods. When determining directions with the compass, graphical methods of obtaining area are reasonably reliable within the limits of accuracy of the instruments. One of these methods consists of adjusting the traverse and plotting it on cross section paper to a convenient scale, preferably so that each square is equal to an even number of square units. For example, make 1 inch equal to 40 feet on cross-section paper having 4 squares to the inch. Then each square is equal to 10 x 10 or 100 square feet. To determine the area, count the squares, assigning fractional values to partial squares, and multiply the total number of squares by the area per square, in this case, 100 feet. This method is convenient where the area of a piece of land such as a burned-over tract, is desired in a hurry. Traversing the perimeter with hand compass and pacing, then plotting and counting the squares is a cheap method of obtaining reasonably reliable information in a minimum of time.

Another rough but rapid method of determining area graphically is to plot and scale the figure in terms of chains. Knowing that 10 square chains equal 1 acre, scale off horizontal parallel lines 10 chains apart. The total length of two adjacent lines in chains divided by 2 would equal the number of acres between the two lines. Repeat this process for the other segments and total. The larger the area, the greater ts the accuracy in each of these cases.

By a variation of this second method, approximate areas may be determined directly in the field. Run a straight line through the center of the area, taking off at right angles every 10 chains in each direction to the edges of the area. The sum of all the lateral distances would give the approximate acreage of the area. This method works particularly well on long narrow strips of land.

48. Area by polar planimeter. The polar planimeter is a device which gives area by traversing the perimeter of the plotted figure. The area in this case is equal to the number of revolutions of the traversing roller times the given con stant for the particular instrument. If work is carefully done, measurements of small areas may be expected to be correct within 1 per cent. Larger areas show precision down to .1 of one per cent.

Section V. Problems.

1. Running one-half mile due West with a declination of 20° 30'East set off on a compass, you end up 45 feet to the North of a point known to be due West of your starting point. What declination should you have used to run this line?

Answer: 21° 30'E

2. A lookout sights to two objects on a ridge 5 miles away. The Azimuth on one object is 183°; on the other, 185 $1/2^{\circ}$. What is the approximate distance between the two points on the ridge?

Answer: 1150 feet

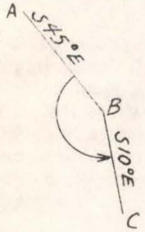
3. Convert the following azimuths to bearings:

	Answers
a. $17^{\circ}\ 30'$	N $17^{\circ}\ 30'$ E
b. $298^{\circ}\ 26'$	N $61^{\circ}\ 34'$ W
c. $359^{\circ}\ 29'$	N $00^{\circ}\ 31'$ W
d. $97^{\circ}\ 20'$	S $82^{\circ}\ 40'$ E
e. $210^{\circ}\ 03'$	S $30^{\circ}\ 03'$ W

4. Compute the angle between the following bearings:

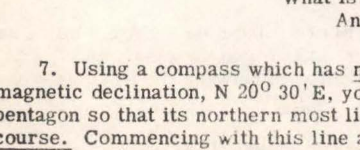
	Answers
a. N $21^{\circ}\ 35'$E and S $89^{\circ}\ 13'$E	$69^{\circ}\ 12'$
b. S $25^{\circ}\ 31'$E and N $87^{\circ}\ 47'$W	$117^{\circ}\ 44'$
c. S $47^{\circ}\ 28'$E and N $01^{\circ}\ 22'$W	$133^{\circ}\ 54'$

5. Given:



Find Angle B.
Answer: 145°

6. Given:



What is Bearing B C?
Answer: S$70^{\circ}\ 00'$E

7. Using a compass which has no means of setting off the magnetic declination, N $20^{\circ}\ 30'$E, you are to lay out a regular pentagon so that its northern most line runs on a true east course. Commencing with this line and running clockwise, what magnetic bearings will you use?

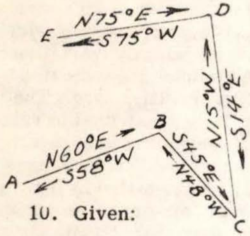
Answer: N $69^{\circ}\ 30'$E, S $38^{\circ}\ 30'$E. S $33^{\circ}\ 30'$W, N $74^{\circ}\ 30'$W.

8. Magnetic declination = 20° 30'E. What is the magnetic bearing corresponding to a true bearing of S 7° E?

Answer: S 27° 30'E

9. Given:

Find Angles B and C, Bearings AB, BC, CD



Answers:
Angle B = 103°
Angle C = 33°
Bearing AB = N 56°E
Bearing BC = S 47°E
Bearing CD = N 14°W

10. Given:

Line	Foresight	Backsight
AB	S. 76° 15'E.	N. 75° 00'W.
BC	N. 65° 10'E.	S. 66° 15'W.
CD	S. 33° 30'E.	N. 32° 15'W.
DE	N. 40° 00'E.	S. 39° 25'W.
EF	N. 45° 20'W.	S. 45° 20'E.

Compute the correct bearing of the line AB.

Answer: AB = S 73° 15'E

CHAPTER IV. INDIRECT MEASUREMENT OF HORIZONTAL AND VERTICAL DISTANCE

Section I. The Aneroid Barometer.

Aneroid (from Greek: a-, not + neros, wet) means without liquid.

49. Description. The aneroid barometer is an instrument for measuring air pressure. It is a vacuum box with one very sensitive side which fluctuates with the variations in atmospheric pressure. These variations are indicated by a needle actuated mechanically by the sensitive side. The scale is graduated in the number of inches required to raise a column of mercury under various amounts of pressure. Because air pressure becomes less as elevation increases above sea level, a second scale may be graduated in feet to give approximate elevations. However, air pressure varies considerably even at the same elevation, so that altitudes are not accurate. At best the instrument is useful for giving relative differences of elevation between two points over short periods of time.

50. Types. The basic principle is the same for the various makes of aneroid barometers. Most of them have foot scales graduated to the nearest 50 feet. Some have verniers enabling one to take readings to the nearest 5 feet. The altimeter, using the same system, will give fairly accurate readings. However, all aneroid barometers are affected by ever changing air pressure which of course reduces their value for accurate work. Figure 16 illustrates one of the makes of aneroid barometers.

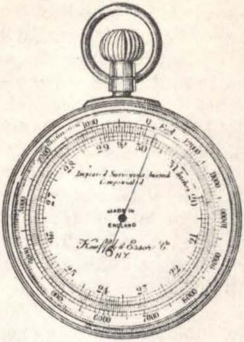


Figure 16. The aneroid barometer.
(Courtesy of Keuffel & Esser)

51. Accuracy. Due to the various limitations placed upon the barometer by the constantly changing atmospheric pressure, it is recommended for use where the accuracy required is of a low degree. It is commonly used in conjunction with pacing to determine roughly the difference in elevation between two points, or an approximate per cent of slope that a projected road might take, or to construct quickly and cheaply a reconnaissance type map or timber cruiser's map where distances are paced and the contour interval is 50 feet or greater. Best results are obtained when one is able to tie to points of known elevation every two hours, or less, correcting readings to these known elevations as explained in article 54. On days of changing weather conditions it is advisable to forego entirely the use of the aneroid.

52. Adjustment. With the majority of aneroid barometers having foot scales on the dial, the elevation of a point can be set by means of a knob or set screw. Therefore, for purposes of measuring the difference in elevation it is not important that the instrument be calibrated so that the inches of barometric pressure are correct. The important point is that it read correct differences in elevation when the air pressure is constant. If it does not do this, the instrument should be returned to the manufacturer for correction. To check the instrument, first tap the glass lightly with the forefinger.

The needle should move slightly, each time returning to its original position, otherwise it is out of order. Next, stand at a point of known elevation and set that elevation on the foot scale. Go to another point of known elevation, 50 to 100 feet higher or lower and read it again. If the elapsed time between the two readings is but a few minutes, the barometer should read the elevation of the second point. By checking in this way several times, one can determine how much the instrument is in error. The same result can be accomplished from only one known elevation by making two or three trips to a point of unknown elevation and return; for example, from the basement to the top story of a building. If one has a barometer that is known to be reliable, he can readily check the new barometer with that.

53. Care of the instrument. Because the aneroid barometer is a delicate instrument, it should be handled carefully and protected from blows. When not in use, it should be in its leather case. The flexible diaphragm is easily damaged and is sometimes affected by extreme heat. For this reason it should be kept away from stoves and heaters. The normal heat of the body or of the instrument itself does not affect those aneroids marked "compensated". If it has been used in wet weather, it should be thoroughly dried before putting it away.

54. Field procedure. In order to secure reliable results with the aneroid barometer it should be in adjustment as described in article 52. After adjustment, it is ready for field use. Simply set the known or assumed elevation of the starting point opposite the needle, read and record successive elevations at subsequent stations, together with the time of each reading. The following precautions should be observed:

a. Before reading, tap the instrument gently on the glass to insure that all working parts are freed.

b. After arriving at a point where it is desired to take a reading, wait a few minutes to allow the needle to catch up with you. There is a natural lag in the needle in adjusting to the pressure change due to the difference in elevation.

c. Always hold the barometer in the same position to read.

Some instruments vary as much as 50 feet between the horizontal and vertical position.

d. Because the possibility exists of the foot scale being moved off its setting when the aneroid is placed in or out of the case, note and record a point where a foot graduation corresponds with an inch graduation on the other non-movable scale. Check this each time to be certain that there has been no movement of the scale.

e. Take advantage of every opportunity to check in to points of known elevation.

55. Methods of correcting readings. As has been observed, barometer readings are constantly affected by changing air pressure. Consequently, there are several methods used to correct the observed readings. These are described as follows:

a. By two readings on an initial point of known elevation. The known elevation is set on the foot scale and the time recorded. Record the successive elevations and times of the several points desired, returning to the original point within two hours if possible and recording the observed elevation and time again. The difference between the known elevation and the final reading represents the error caused by changing air pressure. Within the two-hour period this change can be considered to be uniformly proportional to the time that has elapsed. The correction at any point is equal to the elapsed time required to reach that point times the total correction and this quantity is divided by the total elapsed time. Stated differently, the direct proportion becomes: the correction at any point is to the total correction as the elapsed time to that point is to the total elapsed time. One must be careful to make the correction in the right direction. This is simple if it will be remembered that the correction takes the opposite sense of the error. If the total error is plus, the total correction is minus, and each of the intermediate corrections are minus. For example, suppose the starting elevation is 500 feet and 600 feet is read upon returning to the initial station. What must be done to make the final reading equal to the original setting? The error is plus 100 feet; the correction is minus 100 feet. Therefore, (600 - 100 = 500), and all other corrections take the minus sign.

Some have advocated proportioning the corrections directly as to the distance covered. This proposal assumes that the surveyor travels at a uniform rate of speed, and if that were always possible, the system would be satisfactory. However, that would still be proportional to time, and it is not always possible to travel at a uniform rate, particularly if one is observing details pertinent to his work, perhaps even eating lunch en route. He may make a direct trip back which requires less than half the time it took to cover the route previously. Obviously corrections made on the basis of distance would be faulty in this case.

b. By use of control points of known elevation. In mapping forest areas a skeleton or framework of control points is established prior to the actual mapping itself. This skeleton is usually set up by one of the several more accurate methods in order that the control points will have dependable elevations. For contour intervals of 50 feet or more, the barometer has been found to be a practical instrument for carrying on the mapping between the control points. Results are satisfactory if the control points are no more than one half mile apart in which case it will require about two hours to map from one control point to another. Each strip is then corrected as explained in paragraph a above, the only difference being that instead of tying back to the initial point, the strip is tied to another point of different elevation. The procedure is the same and should be based on elapsed time. One large company in the Northwest has found this method of mapping to be entirely satisfactory for areas where the method of logging is by tractor or high lead and the hauling method is by truck. Railroad logging requires a map of much greater accuracy, but truck roads and logging settings for the former methods usually can be located satisfactorily from a map based on this method.

By this method, transit controls are set every two miles, double abney controls every half mile, and the barometer is used to map the half mile areas between. The controlling factor in this case is that the topographer be able to tie to a point of control within a two hour period.

c. By use of a camp barometer. The camp barometer, so called because it is in theory left at camp, is used to indicate the amount of change at regular intervals during the day. Where it is not possible to tie to points of known elevation

during the day, one barometer is left at the initial point near the area to be mapped with a man to record the readings and the time at regular intervals. At the beginning of the day all barometers are coordinated and all watches are synchronized. At the end of the day a curve of camp barometer readings has been plotted with difference in elevation over time, (figure 17). The observed elevations taken in the field are corrected accordingly, adding to the field readings all differences below the zero index and subtracting those above. This method is satisfactory when the camp barometer is located reasonably close to the field work so that changes in air pressure will affect all barometers by approximately the same amount.

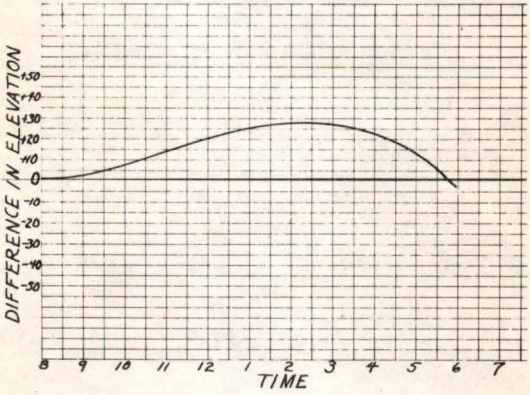


Figure 17. Camp barometer curve.

d. By use of a barograph. A barograph is a self-recording barometer which accomplishes the same thing as the camp barometer. Its disadvantages are: (1) it is more delicate than the camp barometer and (2) it records on a curve usually too small to make accurate corrections.

Another method of correcting barometer readings is by determining the rate of change, i.e., taking two readings at every point at a specified interval apart. From these readings, the rate of change can be determined. However, this requires a sensitive instrument and more time on the part of the indi vidual, so its use is not recommended. It is believed that at least one of the above methods can be used under any conditions in preference to the rate of change method, and more accuracy will result as well.

Air temperature affects air pressure but not to such an extent to warrant making a correction in forest surveying on that account alone.

56. Field notes. Figure 18 illustrates a set of sample field notes for the single point method of correcting aneroid barometer readings.

STA.	DIST. (FT.)	TIME	OBS. ELEV.	ELEV. CORRECTION	CORRECTED ELEV.
A		8:00	500 BM	—	—
	1000				
B		8:15	600	+20	620
	1000				
C		8:45	1300	+60	1360
	1000				
D		9:15	1200	+100	1300
	3000				
A		9:45	360	+140	500

Figure 18. Sample field notes for aneroid barometer work.

57. Sources of error. Errors may be caused in aneroid barometer work by any one or several of the following factors:

a. Careless handling of the instrument which would cause it to get out of adjustment.

b. Extreme fluctuations of air pressure during period used.

c. Failure to tie to points of known elevation whenever possible.

d. Maintaining camp barometer too far from field work.

e. Reading the instrument too soon after arriving at a station.

f. Failure to hold the barometer in the same position for each reading.

g. Correcting readings in the wrong direction.

h. Making corrections proportional to distance instead of to time.

i. Using the barometer at extreme elevations (sea level or over 10,000 feet). The foot scale is graduated evenly, whereas a change at sea level might be only 900 feet,per actual 1000 feet, and at 10,000 feet it might change 1200 feet per 1000 feet. For normal usage at middle elevations results are entirely satisfactory within the accuracy limits of the instrument.

Section II. Abney Level. General.

58. Units of measurement. The common types of abney levels measure the angular relationship between the horizontal plane and the line of sight along a slope in terms of per cent, topographic units, or degrees. Knowing that angle and the slope distance one is then able to determine the difference in elevation and the horizontal distance indirectly.

59. Description of instrument and principles involved. The three main types of abneys are essentially the same except for the graduations on the scales. As illustrated in figure 19, it is basically a square tube in which is mounted a prism, an eyepiece in one end and a horizontal wire at the other, and to which is attached a graduated scale with an indicator arm and level vial mounted at the center of the scale.

When sighting through the tube the level vial is reflected through the prism to the eye and is seen coincidentally with the sighted object beyond the cross wire. The indicator arm is moved until the bubble is split by the etched line on the prism coinciding with the cross wire. The angle is read off the scale at the indicator arm. The bubble represents the horizontal line and the line of sight is the slope line. Since the abney is generally used with the steel tape, the primary requirement is that the tape be held parallel or coincident with the line of sight. It is often difficult to hold the abney steady while learning to use it. This is facilitated by bracing the arms against the chest and holding the breath while centering the bubble.

60. Types of abneys. The per cent abney measures the number of feet rise per 100 feet on the horizontal. Table 5 in the appendix is furnished for determining the horizontal distances and vertical distances corresponding to various slope distances and abney readings. When the horizontal distance is known, the difference in elevation is equal to the horizontal distance times the abney reading divided by 100.

The topographic abney measures the feet rise per chain (66 feet). Table 4 in the appendix lists horizontal distances for various slope distances and abney readings, and, as explained in section IV, the surveyor's tape with its trailer is used to establish this relationship. It is always necessary to compute the difference in elevation, a simple step as follows: Difference in elevation in feet is equal to the horizontal distance in chains times the abney reading.

It will be observed that there is a definite relationship between the readings of these two abneys, since 66 feet is approximately 2/3 of 100 feet, the bases for the topographic and per cent abneys respectively. Per cent readings can be

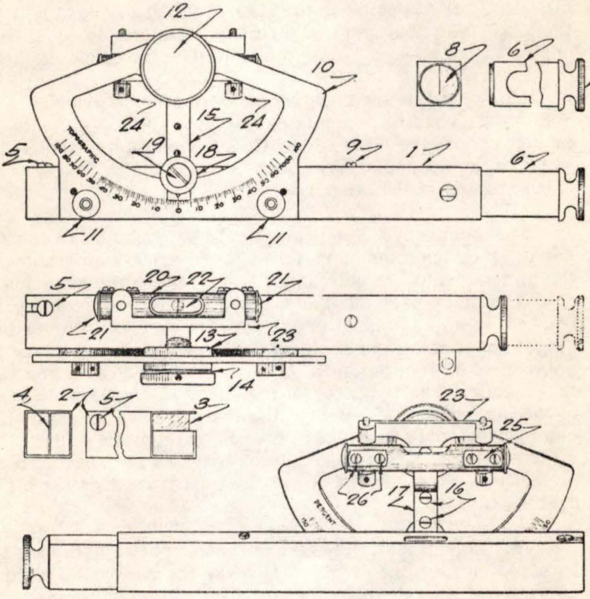


FIGURE 1

1. Telescope tube.
2. Prism and cross-hair slide.
3. Prism.
4. Cross-hair slide.
5. Prism slide lock screw.
6. Slide tube.
7. Eyepiece cap.
8. Half lens.
9. Slide tube lock screw.
10. Graduated limb.
11. Limb capstan nuts.
12. Main capstan bolt.
13. Main clamp nut.
14. Spring washer.
15. Index arm.
16. Index arm screws.
17. Index arm lock bar.
18. Index arm lock nut.
19. Lock nut screw.
20. Vial tube.
21. Vial tube ends.
22. Glass vial.
23. Vial bracket.
24. Capstan adjusting screws.
25. Capstan screw anchor.
26. Capstan screw anchor screws.

Figure 19. The abney hand level.

roughly converted to topographic by multiplying by 2/3, and vice versa by multiplying by 3/2.

The degree abney measures the angle between the slope and the horizontal to the nearest degree. The difference in elevation here is equal to the sine of the abney reading times the slope distance, and the horizontal distance is equal to the cosine of the abney reading multiplied by the slope distance.

Many abneys are constructed with a scale graduated on both sides, reading per cent on one side and topographic units or degrees on the other side. Conversion tables (tables 1, 2, and 3 in the appendix) have been constructed to convert one unit to either of the other two.

61. Accuracy. The precision to be expected from the abney depends upon the experience of the crew, topography, and the method used. Double abney work, where the head and rear chainman each have an abney, tends to eliminate some error in reading which means more accurate results. For ordinary single abney work the accidental errors that accumulate should not exceed 10 feet per mile in elevation nor 30 feet per mile in distance. The accuracy of the abney is comparable to that of the staff compass. Hence, the two are used extensively in combination when mapping. The abney might be called a middle precision instrument lying between the aneroid barometer on the low precision side and the transit on the higher precision side.

62. Adjustment. There are three field adjustments to be made on the abney level: (1) make the horizontal wire correspond with the etched line on the prism by moving the prism and cross-hair slide in or out when the indicator is on zero, then tightening the lock screw: (2) adjust the height of the glass level vial above the tube so that the cross hair and the etched line coincide at steep angles (at steep angles the bubble appears crescent shaped in which case the etched line should appear near the concave side of the bubble): (3) make the level vial parallel to the line of sight by the "two-peg method" (figure 20) as follows: Set the abney at zero and sight from a point A on a pole or tree to a point on another tree 50 to 100 feet distant. Mark this point B. Take the instrument to point B and with the instrument still at zero sight back to the original tree and make a mark C directly above or below

point A. Establish point D halfway between A and C and by adjusting the capstan screws holding the level vial, center the bubble while sighting from B to D with the indicator still at zero. BD is a level line. Level lines may also be established by means of a transit or engineer's level if they are in adjustment. These adjustments, particularly the last one mentioned, should be checked each time the abney is taken into the field.

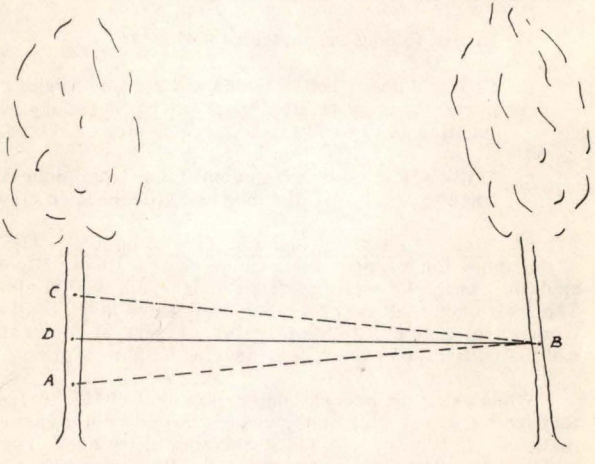


Figure 20. Two peg method of adjustment of the abney hand level.

63. Care of the abney. The abney is one of the most rugged instruments used in surveying but like most surveying instruments, careless handling will cause it to get out of adjustment. It should be carried in the case when not in use. Avoid dropping or knocking the instrument; dry it off after use in wet weather, and make certain that all nuts are snug. When adjusting the abney, never cinch down on nuts or capstan screws, as the threads are easily stripped.

64. Sources of error. Because the line of sight begins at the operator's eye and not at the ground, he must sight at the

same height above the ground on the object or chainman. When he starts the work, he should set the indicator at zero and stand on level ground about 6 feet away from his chainman and sight a level line to the chainman to determine where the line of sight hits him. If the two are of the same height, the line would strike the chainman at eye level. This principle is often violated and becomes a common source of minor errors, reaching large proportions over long traverses. The line of sight should always be parallel to the tape if accurate work is to be expected. Other sources of error are:

a. Failing to hold the instrument steady.

b. Calling a plus reading minus and a minus reading plus, particularly on small slopes, where there may be a question as to whether the slope is plus or minus.

c. Arithmetical mistakes in converting from slope distance to horizontal distance and difference in elevation.

65. Uses of the abney and auxiliary equipment. The use of the abney for mapping and running control lines will be explained in the following sections under each type of abney. The instrument has various other uses which make it an extremely valuable tool to the forester. Figure 21 illustrates its use by the timber cruiser in measuring heights of trees.

When using the percent abney, note that at 100 horizontal feet from the tree each abney reading represents a vertical distance. In figure 21, A and B, the sum of the abney readings, and in C the difference of the abney readings gives the total height of the tree in feet. If the horizontal distance is more or less than 100 feet, it must be multiplied by the abney reading and divided by 100 to get the vertical distance. Two convenient distances commonly used, other than 100 feet, are 50 feet for short trees and 200 feet for extremely tall trees. At 50 feet the vertical distances are one half the abney readings and at 200 feet the vertical distances are twice the readings. If the topographic abney is used, the base horizontal distance becomes one chain or 66 feet. The same principles apply as with the percent abney. Inspection of figure 21 will show the trigonometric principles used with the degree abney to solve for the vertical distance, namely, the slope distance times the sine of the abney reading, or the horizontal distance times the tangent of the abney reading.

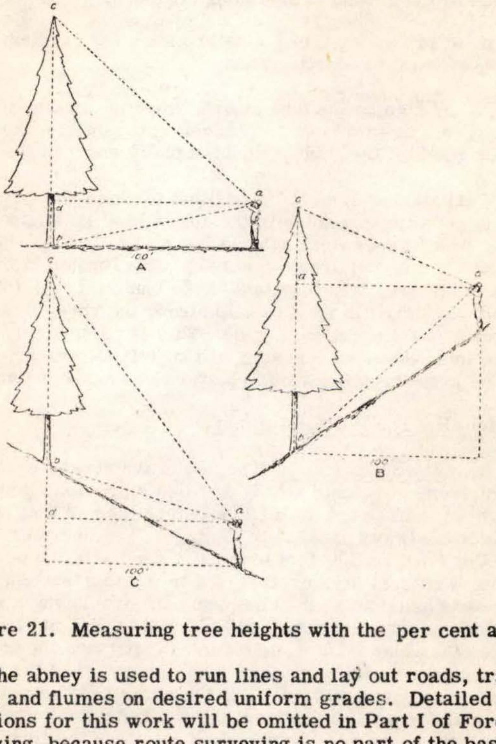


Figure 21. Measuring tree heights with the per cent abney.

The abney is used to run lines and lay out roads, trails, chutes and flumes on desired uniform grades. Detailed instructions for this work will be omitted in Part I of Forest Surveying, because route surveying is no part of the basic course for which this text is designed.

Other uses of the abney are as follows:

a. By setting the abney at zero it can be used as an ordinary hand level in the same manner as the Locke level,

a sighting tube with level vial rigidly attached. The abney is thus used to measure directly the differences in elevation for determining grade and locating slope stakes in route surveying. It is likewise used to determine a level line along the surface of the ground in sketching contours.

b. It is a handy tool for determining the gradient of a ridge, stream, or existing road.

c. By holding the tube at arm's length, making it appear to rest on a distant ridge, and leveling the bubble, the slope can be read off the scale without actually going to the ridge.

Auxiliary equipment, in addition to chain and compass, that is sometimes used with the abney is a flashlight and a staff. Much abney work is done in brushy country. Since a line of sight is required, sights are often limited in distance. A flashlight will help to extend these shots through foliage and brush. The staff is used to help steady the abney where the operator has difficulty doing so. This is particularly helpful to the inexperienced operator, although it is recommended that he practice without this additional encumberment.

Section III. The Per Cent Abney.

66. Field procedure. The use of the abney requires that the instrument be held steady and that a previous level line (height of instrument or H.I.) be determined so that the line of sight is always parallel to the tape. The engineer's tape in 100-, 200-, or 300-foot lengths is used with the per cent abney. Efficient organization of a two-man crew usually finds the head chainman as the compassman, prolonging his line of sight by natural landmarks and his own backsights independent of the other man. The rear chainman operates the abney and keeps notes. In this way each man is busy all of the time, the former prolonging his line, and the latter keeping notes. If double abney work is desired, the head chainman also has an abney. When the tape is stretched out along the line, the slope distance is measured and the abney is read immediately, so that the notekeeper has the information needed to complete the notes and the compassman has plenty of time to line up his next forward shot. There is no need of either man holding up the other. This system is especially adaptable to topographic mapping, where the notekeeper is also the topographer.

Tables are necessary with the per cent abney for determining the horizontal distance and the difference in elevation. The most useful tables devised for this purpose are those compiled by Lester Calder of Weyerhaeuser Timber Company (see table 5, appendix). These are graduated vertically in 10's of feet from 40 to 300 feet and horizontally in terms of per cent from 6 per cent to 80 per cent, each per cent having its corresponding angle given in terms of degrees and minutes. For 81 to 150 per cent the corresponding angle is given with its sine, and cosine. While it is possible to interpolate directly in the tables between the 10's of feet, a simpler method is proposed. When one becomes familiar with this method, he will find it much easier than direct interpolation, and less chance exists for arithmetical error. The following examples best explain:

Use an abney reading of 50 per cent in each case.

slope distance	Look opposite	hor. dist.	diff. elev.
a. 20	200 and take 1/10 of the figures:	17.89	8.94
b. 139	100 and record directly:	89.4	44.7
	300 and record 1/10 of it:	26.83	13.42
	90 and record 1/10 of it:	8.05	4.03
	Hor. Dist. and D.E. = total	124.28	62.15
c. 321	300 and record directly:	268.3	134.2
	200 and record 1/10 of it:	17.89	8.94
	100 and record 1/100 of it:	.894	.447
	Hor. Dist. and D.E. = total	287.084	143.587

While this is an efficient method of reducing to horizontal and vertical distances when odd lengths are measured, it is advisable for the sake of time and accuracy to break chain whenever possible at the nearest 10 feet so that the reduction may be read directly from the table.

It will be noted that the tables decrease to a minimum of 6 per cent. For slopes less than 6 per cent it is assumed that the chainmen will measure horizontal distance, breaking chain at 100 feet and taking care to hold the low end of the tape up as many feet as the abney reads in per cent. For example,

the abney reading is plus 5 per cent. The rear chainman holds his end of the tape 5 feet high and the head chainman holds the zero end on the ground. The difference in elevation is $\frac{5 \times 100}{100}$ or 5 feet in this case. If distances are to the even 100 feet, the abney reading is equal to the rise.

Short distances of a few feet are usually taped horizontally, the distance multiplied by the abney reading and divided by 100 to get the difference in elevation. This is illustrated in figure 22 in the note form where it is desired to measure an even 500 feet. The last distance is chained on the level, and the difference in elevation is computed. Where it is possible to tape horizontally, the slope distance is obviously not required since it is merely a figure used to determine horizontal distance and elevation difference.

67. Field notes. Whether for running controls in mapping or for running strips, the following note form is ideal for the per cent abney:

STA.	HOR. DIST.	SLOPE D. % ABNEY	D.E	ELEV	BRNG.
$5+00^{\underline{0}}$				534.5	
	3.8	——	−0.8		
$4+96^{\underline{2}}$		−20		535.3	
	$99^{\underline{5}}$	100	−10.0		
$3+96^{\underline{7}}$		−10		545.3	
	$98^{\underline{9}}$	100	−14.8		
$2+97^{\underline{8}}$		−15		560.1	
	$109^{\underline{6}}$	115	+35.0		
$1+88^{\underline{2}}$		+32		525.1	
	$88^{\underline{7}}$	90	+15.1		
$0+99^{\underline{5}}$		+17		510.0	
	$99^{\underline{5}}$	100	+10.0		DUE S
$0+00^{\underline{0}}$		+10		500.0	

Figure 22. Note form for the per cent abney.

Section IV. The Topographic Abney.

68. Field procedure. The mechanical process of operating the topographic abney is exactly the same as with the per cent abney, the difference being in the construction of the scale and what is done with the reading after it is obtained. Because this abney is used with the topographic or surveyor's tape, it measures feet rise per chain or 66 feet. To adapt this tape for use with the topographic abney and to eliminate the need for slope reduction tables, a "trailer" is built into the tape. The graduations on this trailer represent the difference between slope and horizontal distance at various abney readings. The numbers are topographic units. The slope distance is the hypotenuse of a right triangle and is longer than either of its other two sides. As the angle of slope increases, so does the abney reading and the slope distance. It is upon this principle that the trailer is graduated. With the two-chain tape which is commonly used (there are also three- and five-chain tapes), two trailers are furnished, one for distances of one chain and one for distances of two chains. The former is found beyond the one-chain brass tab on the underneath part of the tape. Beginners must be careful not to confuse the distances in the top forepart of the second chain with the trailer graduations underneath. The second trailer is actually tacked on at the end of the two-chain brass tab. Figure 23 illustrates this principle, where two chainmen are measuring downhill. The procedure is the same uphill.

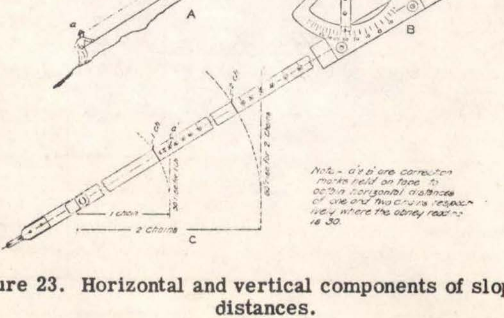


Figure 23. Horizontal and vertical components of slope distances.

Using this example, the procedure is as follows: The head chainman goes down the slope a distance of two chains, and the rear chainman reads -30 on the abney. He finds 30 on the trailer and has the head chainman move down the slope to put tension on the tape. The abney is read again. If it is still 30, the point is set. If the slope has changed slightly when the head chainman moved to the new point, the distance is adjusted to the correct trailer graduation. Then the chainmen are two horizontal chains apart and somewhat farther on the slope. They need not know the slope distance, for it is horizontal distance they want. The horizontal distance in chains multiplied by the abney reading gives the elevation difference. The steps are the same for one-chain distances, using the one-chain trailer. In this case, the abney reading is the difference in elevation.

The topographic abney and tape permit faster and cheaper work where it is possible to take all distances to the nearest one or two chains. However, the work is delayed if it is necessary to make frequent measurements in fractional tape lengths. It is usually required to break tape when tying into bench marks, land subdivision corners, or other established points, or when coming to abrupt breaks in slope, such as stream crossings, ledges, and ridges.

Fractional slope distances are reduced to horizontal and vertical distances by any one of three methods: (1) tables, (2) formula, or (3) taping horizontal distance direct. The reduction table shown in the appendix gives distances in links, every two links up to 100, and abney readings to the nearest 5 units. This frequently requires double interpolation. The table does not go beyond one chain, because it is always possible to measure to the nearest one chain and reduce with the one-chain trailer. The remaining fractional part of a chain is measured by one of the three systems.

Where slopes are small or distances are short, it is recommended that horizontal distance be taped directly, using the abney as a level to assure oneself that the tape is horizontal. Then multiply the horizontal distance in chains by the abney reading to get elevation difference as would be done regardless of which of the three methods are used. For steeper and longer slopes, direct horizontal measurement may become a frequent source of error; therefore one of the other two methods would be advisable.

A reduction table is seldom taken into the field with the topographic abney and chain. Therefore, it is sometimes necessary to resort to formula to obtain the horizontal distance. This formula is a direct proportion based on the principle of similar triangles. The right triangle formed by the slope distance, the vertical distance, and a horizontal distance of one chain is similar to a smaller triangle of the same slope angle and a horizontal distance of less than one chain. The one instance where slope distance is required is in solving this proportion. Take the abney reading for the particular slope and find that reading on the one-chain trailer. Turn the tape over and observe the actual distance to that abney reading on the trailer. This gives the slope distance for one horizontal chain. Next, measure slope distance to the point in question. The slope distance for one chain is to one horizontal chain as the measured slope distance is to the unknown horizontal distance. In other words, the horizontal distance for a fractional part of a chain is equal to one chain times the measured slope distance divided by the slope distance for one horizontal chain. Since one chain is unity, the formula is simplified to:

$$\text{Sought horizontal distance} = \frac{\text{measured slope distance}}{\text{slope distance for 1 horizontal chain}}$$

For example, suppose the abney reading is 50 and the taped slope distance is .84 chains or 84 links. It is desired to find the corresponding horizontal distance and the elevation difference. Find 50 on the one-chain trailer, turn the tape over, and read 125.5 links, interpolating for the tenths of a link. This is 1.255 chains. Substituting in the formula:

$$\text{H. D.} = \frac{84 \text{ links}}{125.5 \text{ links}} = 67.0 \text{ links, or .67 chains, the desired}$$

horizontal distance. This horizontal distance in chains multiplied by the abney reading, 50, is equal to 33.5 feet, the difference in elevation.

69. Field notes. Figure 24 illustrates a simple field note form for the topographic abney. Notice that the station column carries the accumulated horizontal distance in chains and hundredths.

STA	HOR DIST	ABNEY	D E	ELEV	BRNG
3.70				564	
	.70		-7		
3.00		-10		571	
	1.00		-10		
2.00		-10		581	
	2.00		+48		DUE N
0.00		+24		533	

Figure 24. Note form for the topographic abney.

Section V. The Degree Abney.

70. Principles. The degree abney measures the vertical angle between the line of sight and the horizontal to the nearest even degree. Therefore, the horizontal and vertical elements are found by multiplying the slope distance by the cosine and sine functions of the vertical angle respectively. The engineering staff of one of the larger lumber companies in the Northwest prefers the degree abney to the others, having constructed tables similar to those shown in table 5 in the appendix for the per cent abney. These tables give the horizontal and vertical distance for various angles of slope and slope distances. The values have been worked out from the standard sine and cosine tables.

Choice of which abney to use depends somewhat upon the preferences of the individual himself or his employer. Most of the private companies prefer the per cent abney or the degree abney, while state and federal agencies seem to favor the topographic abney. The student should know the principles of each and be prepared to use any one of the three.

Section VI. Problems.

1. Aneroid barometer reading at Sta. A is 1000. Returning to Sta. A 4 hours later you read 1200. (a) The rate of change is how many feet per half-hour? (b) What would be the correction 1 1/4 hours before you returned?

Answer: (a) 25 feet (b) 137.5 feet

2. Calculate the correct elevation, of the following aneroid barometer notes

Time	Camp Baro.	Field Baro.	Cor. Elev.
8:00 a.m.	1500	830	830
9:00 a.m.	1525	970	(a)_____
10:00 a.m.	1540	1085	(b)_____
11:00 a.m.	1555	1195	(c)_____

Answer: (a) 945 (b) 1045 (c) 1140

3. The per cent scale of the abney hand level reads plus 16 1/2 between 2 points 223 feet (horizontal) apart. What is the vertical distance to the nearest 1/10th foot?

Answer: +36.8 feet

4. The topographic reading of the abney hand level reads Minus 26 between 2 points 1.86 chains (horizontal) apart. To the nearest hundredth of a foot, what is the vertical distance?

Answer: 48.36 feet

5. Between 2 stations the horizontal distance is 122 feet and the vertical distance is 64 feet. What is (a) the per cent abney reading? (b) The topog Abney reading? (c) The degree abney reading?

Answer: (a) 52.5 (b) 34.6
(c) $27^{\circ} 41'$ or 28°

6. A road rises uniformly for a distance of one-eighth mile. With a topographic abney you sight up the road and read 4 on the scale. What is the percent of grade?

Answer: 6+%

7. Per cent of slope of a road is 8.63. What is the degree of slope? (Use trigonometry)

Answer: 4° 56'

8. The difference in elevation between 2 points is 12.5 feet and the abney reading is 17%. (a) What is the horizontal distance between the 2 points? (b) The slope distance?

Answer: (a) 73.53 feet
(b) 74.57 feet

9. A railroad spur leaves the mainline at an elevation of 826.4 feet. The RR spur which is located on a sustained grade of plus 3% is 1200 feet long. What is the elevation of the spur at the back end?

Answer: 862.4 feet

10. From station A (elev.= 500 feet) you measure 5 chains horizontal to Station B and read -3 on the topographic abney. What is the elevation of B?

Answer: 485 feet

11. In tying in to a station you measure the slope distance (72 links) and read 40 on the topographic abney. The trailer distance to 40 on the one chain trailer is equivalent to 17 links. What is (a) the horizontal distance and (b) the vertical distance?

Answer: (a) 61.5 links (b) 24.6 feet

12. A truck road is to be constructed up a canyon, terminating at a saddle with an elevation of 5500 feet. The point of origin has an elevation of 3000 feet. The horizontal distance is five miles. (a) If no additional distance can be secured, what is the average grade? (b) How long will the railroad be if the average grade must be held down to 4 per cent?

Answer (a) 9.47% (b) 11.8 miles

13. The height of a ponderosa pine growing on level ground is known to be 90 feet. As a timber cruiser you stand 200 feet from the tree in a position where the abney reading

measures the angle between the horizontal line (intersects base of tree) and the line of sight. The readings on the various abney scales would be what?

Answer: (a) per cent = 45
(b) topographic = 30
(c) degree = $24^{\circ} 14'$

CHAPTER V. FOREST MAPPING

Section I. General Considerations.

71. Public land survey. As previously stated, a complete discussion of the laws and methods governing the survey of public lands in the United States is beyond the scope and purpose of this manual. A common weakness of graduates is their limited knowledge of these laws. This is due partially to incomplete and hasty coverage of the subject. One must go into it thoroughly or not at all. The saying, "A little knowledge is a dangerous thing," is certainly applicable in this case. Because public land survey is omitted here, a list of the important publications treating it must suffice.

The most complete reference is the Manual of Instructions for the Survey of the Public Lands of the United States, edition of 1947. Extracted from the manual is another abbreviated publication, Circular 1452, Restoration of Lost or Obliterated Corners and Subdivision of Sections. Both of these publications of the General Land Office are on sale to the public (at current cost of printing) by the Superintendent of Documents, United States Government Printing Office, Washington, D.C. Many of the current surveying texts clearly describe the system and give methods of subdividing sections. However, space does not permit them to cover the subject as completely as in the government manual itself.

72. Planimetric maps. Forest maps can be classified generally into two groups: planimetric and topographic. The former shows detail in a flat two-dimensional plane only. Topographic maps show terrain in three dimensions by use of various symbols.

Planimetric maps illustrate relative locations of objects on the ground such as buildings, roads, and streams; they designate boundaries of land subdivisions such as farms, counties, and unfenced ownership. Included under boundary designation are "type lines", fine dotted lines which denote changes in vegetation types, as from open country to brush, brush to timber, Douglas-fir to alder, and so on. Several types may be shown also by the use of colors. A "type map" is a planimetric map showing these features. Other examples of planimetric maps are some highway maps, township plats,

county ownership maps, and various maps of extremely large areas, showing no relief.

73. Topographic maps. There are five principle ways of showing relief, any one of which gives a map its third dimension and classifies it as a topographic map. These methods are by color, hachures, shading, contours, and by construction of an actual scale model of the area. The latter is referred to as a relief map. It is built up of layers which are trimmed off to show the configuration of the earth's surface as it appears on the ground. Each layer is equivalent to a specified vertical distance, so that the vertical scale is accurately shown. Maps covering large areas, such as a continent, will sometimes have a specific color to denote each 1000 feet (or other unit) in elevation above sea level. Hachures are short, straight lines used to denote ridges, peaks, and drainage. The closer the hachures, the steeper the slope depicted. Likewise is this true in shading. Steeper slopes are darker shaded. Contours are considered the most effective method of showing relief, and they are most commonly used in forest mapping. They are discussed in article 74, following.

74. Contours. A contour is an imaginary level line on the surface of the ground. It may be thought of as the trace formed by the intersection of the shore line of a lake with the ground surface. When the contour or contour line appears on a map it indicates elevation above mean sea level. The vertical distance between two contours is known as the contour interval. The choice of contour interval depends upon the roughness of the terrain, the use which is to be made of the map, and map scale.

Characteristics of contours are as follows:

a. They are close together on steep slopes, widely spaced on flat slopes, and they are perpendicular to the line of steepest slope.

b. Irregular spacing of contours indicates an irregular slope, while even spacing denotes a uniform slope. Along plane surfaces they are straight and parallel to one another.

c. Contours do not split on natural objects and they seldom merge or cross except in those instances where vertical or overhanging cliffs are shown.

d. Valley and ridge lines are crossed at right angles, forming an inverted V across a stream and a U around a ridge. Contours cross wide streams as straight lines at right angles to the direction of flow.

e. A contour always closes on itself, either on or off the limits of the map. If it closes on itself within the map boundary, it indicates a summit unless there are short lines drawn within it and perpendicular to it, representing a depression.

f. Contours are usually at evenly-spaced vertical intervals, such as 2, 5, 10, 20, 25, 50, 100, or 1000 foot intervals, depending upon use, scale, and topography. Usually every fourth or fifth contour is a heavier line on which the elevation is labeled. For most forest maps, this line is the 100-foot contour.

A variation of the contour is that known as a form line. Its characteristics are the same as those of a contour, except that a form line may fall at any odd elevation and occur at irregular vertical distances. Form lines are not as useful as contours but they permit faster field work. A contour map constructed from form lines requires more office time and is less accurate than a map based on contours located directly in the field. Figure 25 shows a section of a typical contour map.

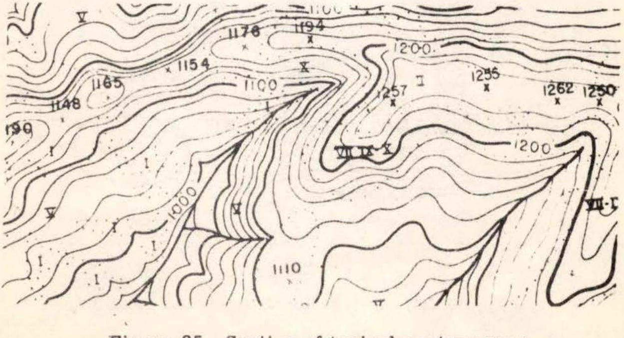


Figure 25. Section of typical contour map.

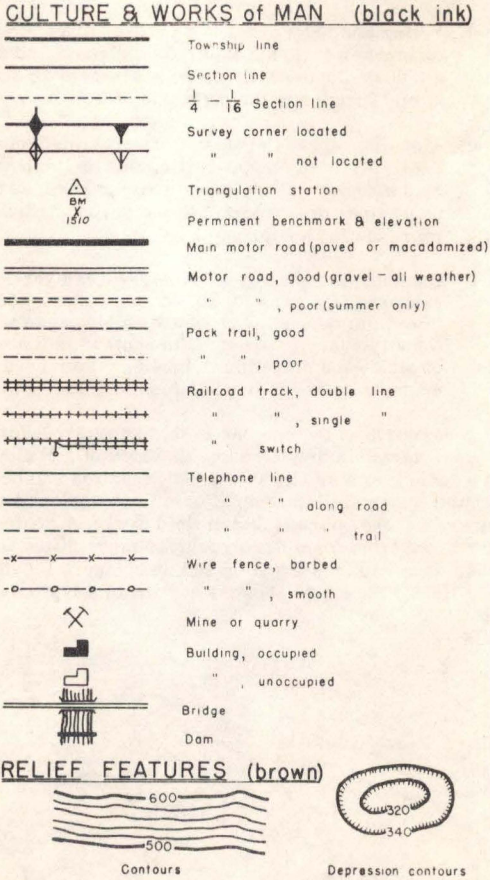


Figure 26. Conventional signs and symbols.

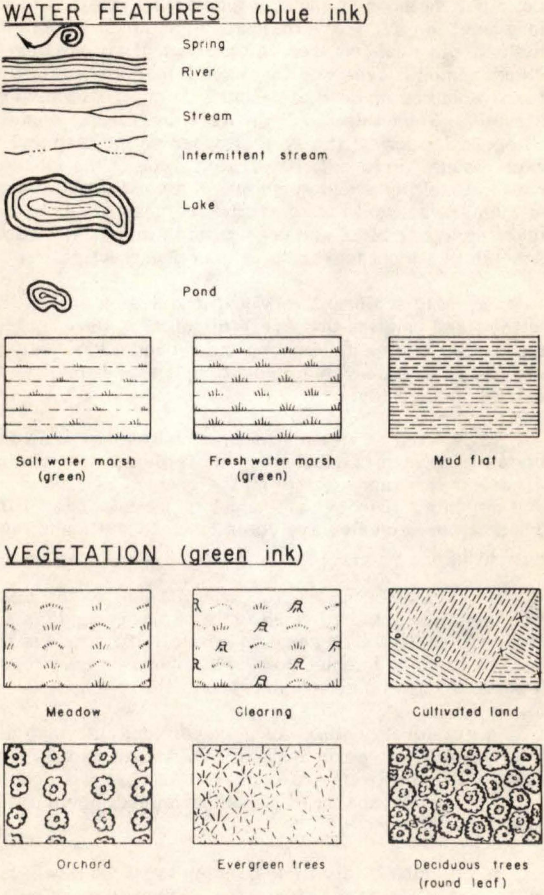


Figure 26. (cont) Conventional signs and symbols.

75. Signs and symbols. Map reading requires that one learn a new language, the language of maps. Contours and the other methods of showing topography are part of that language. So, also, are the many signs and symbols used to indicate physical features on the map. If all symbols were standard and if everyone that used a map knew the symbols, there would be no need of defining them on each map constructed. Since this is not the case, every map contains a "Legend", showing the symbols used on the map and what each means. Figure 26 illustrates some of the more common conventional signs and symbols. Notice that culture and works of man are shown in black, relief features are in brown, water features are in blue, and vegetation is in green. This coloring scheme is almost universal in map construction.

76. Map scales. Every map requires a scale. The scale is the fixed relation that every distance on the map bears to the corresponding distance on the ground. The scale may be expressed as a convenient equation, a representative fraction, or in graphical form.

Expressed as an equation, the scale takes one of two styles: one inch is equal to some whole number of tens, hundreds, or thousands of feet on the ground, as 1 in. = 100 ft.; and a number of inches are equal to one mile, as 16 in. = 1 mi. These types of scales are common on forest maps, and logging plan maps.

A representative fraction shows 1 unit on the map equal to a certain number of equal units on the ground, as 1/62,500 (approximately 1 inch equal to 1 mile). This means that 1 inch on the map is equal to 62,500 inches on the ground. Such a scale is used on geographic and military maps.

A graphical scale is a line subdivided into map distances corresponding to convenient units of length on the ground. Figure 27 shows various forms of this type of a scale. To avoid confusion, the units of measurement should always be stated.

A graphical scale is desired on most maps where there is danger of the paper stretching or shrinking or more particularly, when the map is to be reproduced in a larger or smaller size. In the latter cases, the graphical scale is most imperative.

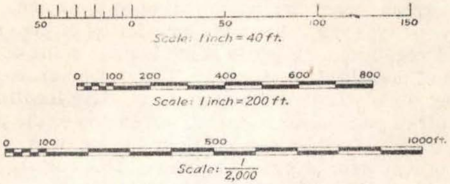


Figure 27. Graphical scales.

Maps are often designated as large scale maps and small scale maps. A large scale map has a large representative fraction (1/1000 is a larger fraction than 1/62,500). In general the scale of a map should be no larger than is necessary to represent the location of details with the required precision.

The scale of a map depends upon the purpose for which the map is to be used. If accurate planning of roads and landings is necessary, as in logging plan maps, the field work must be accurate and the map must be of a reasonably large scale. Hence the accuracy of the field work is proportional to the map scale. The larger the scale, the more intensive should be the field work.

77. Map orientation. A map is of no value if it lacks means of determining direction, or of orienting it. The direction of the meridian (North) is indicated in some convenient place by an arrow. True North is usually indicated by an arrow with full head; magnetic North by an arrow with half head. Where both are shown, the magnetic declination is also given. On most military maps a third meridian, grid North, is indicated also.

Whether to use a true or magnetic arrow or both is not up to the fancy of the person constructing a forest map. He is to be guided by the method in which his control was oriented. If his control was established with a compass, then his map will show both true and magnetic arrows, giving the angle of declination. If the control was done with a transit, oriented by celestial observation, then only the true North arrow is used. The details of the map are corrected to the control, even though detail was established by compass, so the declination used is inconsequential.

78. <u>Types of forest maps</u>. Forest maps are of three general types, depending somewhat upon their use. The inventory, or type map shows the boundaries of the various types of vegetation, giving in some instances the acreage and volume of merchantable timber. The timber cruiser prepares this map form. The plan map gives relative locations of certain desired man-made features, for example, the placement of facilities at a public camp site or the location of buildings in a logging camp. A base map shows both culture and vegetation and usually relief as well. This map may also be used for either of the other purposes. A contour map is a base map which may be used as a logging plan map if the scale is sufficiently large to permit reasonably accurate location work.

79. <u>Methods of mapping</u>. The terms, control and detail, have been used heretofore without explanation. Control in mapping is the framework or skeleton which is surveyed and balanced for purposes of obtaining the correct size, shape, and position of the area to be mapped. Control is of two components: horizontal and vertical. The former defines position of objects in the horizontal plane, the latter establishes elevations. Detail, including relief if shown, is the pattern (tied and corrected to the control points) of the area itself. There are numerous ways to perform these functions, and while the relative merits of each will not be discussed, some of them are listed below for information.

Horizontal control	Vertical control	Detail and relief
triangulation	direct leveling	engineer's level and steel tape
transit traverse	vertical angle with transit	hand level and steel tape
double abney	double abney	strips using: abney, compass and steel tape
single abney	single abney	barometer, compass and steel tape
existing public land survey corners	stadia single point	barometer, compass and pacing
stadia	barometer	stadia
		plane table
single located point		aerial photographs

The methods of performing these functions read generally from most accurate to least accurate, although the relative accuracy of some is debatable, and accuracy is increased or decreased by variations in each method. For example, aerial photographs, if porperly corrected, may become one of the most accurate methods of showing detail and relief, so there is no significance to its location in the list. Likewise, there is no definite correlation reading horizontally, as any specific method of setting horizontal controls requires no single system of placing vertical controls and detail. The important point to remember is that horizontal and vertical controls are usually done with instruments of equal accuracy, while detail and relief are set with instruments of equal or less accuracy.

80. Uses of topographic maps. A large scale topographic map is a valuable asset for planning a woods project. Such a map has many uses, some of which are to determine:

a. location of existing features,

b. horizontal distance,

c. elevations,

d. suitable locations for roads, landings, camps, etc.,

e. areas,

f. drainage data, including water volume for proposed reservoirs,

g. visibility of area from specific points,

h. profile,

i. rate and direction of slope, and

j. volume of cuts and fills.

81. Auxiliary mapping equipment. In addition to the conventional surveying tools described in previous chapters, many useful devices have been perfected to simplify mapping with the standard equipment. One of these is a handy plotting device which decreases the office time required for plotting

the numerical data in field notes. This "pocket plane table" is called the Reinhardt Redy-Mapper, named for Robert Reinhardt, the forester who has patented it under the name of his Woodsman Tool Company of South Tacoma, Washington. It consists of a transparent 360° protractor pivoted through its center on a map board. The map board is marked off in squares with an arrow parallel to the vertical lines in the squares. The lines perpendicular to the arrow are used to scale off distances. Each space represents a desired unit of distance. The lines parallel to the arrow indicate the line of travel. The Redy-Mapper is used with compass and chain or pace. In plotting traverses, a convenient point is chosen and marked on the protractor which takes pencil. The protractor is rotated so that the compass reading is at the arrow. Then the distance is scaled off from the initial point away from the operator and parallel to the arrow. The operation is repeated for each leg of the traverse. If careful work has been done, a closed traverse in the field will likewise close on the protractor, giving a reliable sketch of the boundaries of the area. Detail can be located by side shots from any of the traverse stations. If the area is desired, the squares are counted and their number multiplied by the area per square. If the relative positions of two points can be accurately plotted on the protractor in advance, one can go into the field to one of the points and by following the easiest route, plotting his distances and directions as he progresses, he can take himself to the other point. He knows where he is at all times wtth reference to either of the points. This tool is extremely useful for determining areas quickly, for example, the size of a forest fire when daily reports are required of its status. Its value lies in its simplicity. Anyone who has learned to use a compass and tape (or pace) can look at the Redy-Mapper and learn to use it almost at once.

Section II. Topographic Mapping Procedure.

82. Choice of method. One's choice of the field method to use in constructing a topographic map depends primarily upon the resultant map's intended use. His choice is also influenced by the topography and area of the tract, the scale and contour interval desired, and finally, upon how much money he will be allowed to spend in the construction. He does the most economical job possible in keeping with the required accuracy. Once the decision is made on what method to use, the field work may be started.

The purpose of this section is to outline briefly a mapping procedure of intermediate precision that would permit the use of the surveying instruments discussed in the foregoing chapters. The accuracy of such a map would be consistent with the accuracy of these instruments, approximately 1 to 500, allowing a map scale of 1 inch = 200 feet more or less. Other methods of mapping are variations of the following system, depending upon the accuracy desired. A more accurate map would require transit control and plotting by coordinates, while a reconnaisance type map may be done by pacing, aneroid, and hand compass, using graphical plotting. Knowing one method, it is easy to adapt to the others.

83. Control. Double abney, staff compass, and steel tape are used to establish the control along Public Land Survey lines, assuming that they are reasonably correct. The section lines and corners become the framework for the detail. Stakes are set every 660 feet, starting on the section line 330 feet from the initial corner. The re-measured distances are plotted on detail paper. The elevation of the initial point having been established, vertical control is carried around the rectangular tract along with the horizontal control. Control does not exist until the traverse is closed either on the initial point or on some other known point. In tying back to the original point, the horizontal control closes if the section lines have been followed. The difference between the final elevation of the initial point and its original correct elevation is the error in the vertical control. The elevations of each station back along the traverse are corrected by a straight-line proportion. This is stated in the following formula:

$$Ca = \frac{a}{L} Ec \text{ where:}$$

Ca = the correction at any point along the traverse

a = the horizontal distance to that point

L = the total length of the traverse, and

Ec = error of closure in elevation

For example, suppose that the elevation of the initial point is 500.0 feet, that the length of the traverse is 5280 feet, and that the final elevation of the initial point is 506.2 feet. The error of closure is 506.2 − 500.0 or a plus 6.2 feet. You desire to know the elevation correction at station 26 + 40 (2640 feet from the beginning). Substituting in the formula:

$$Ca = \frac{2640}{5280} 6.2 = -3.1 \text{ feet.}$$ The correction takes the opposite sense of the error and is therefore minus, because the error in this case was plus. If the uncorrected elevation of station 26 + 40 was 1110.3 feet, its corrected elevation would be 1110.3 − 3.1 = 1108.2 feet. When the control has been plotted and the elevations have been corrected, the detail work may be initiated.

84. Detail. Detail is furnished by running strips 660 feet wide through the area with abney, compass, and steel tape. The control points governing the beginning and ending stations of the strips are the stakes which were set in the control at intervals of 660 feet. Eight strips of this width will cover a square mile. Strip forms are previously prepared on some suitable type of cross-section paper, where each square is made to represent a convenient unit of measurement according to the desired scale. They should be long enough to encompass the entire length of the strip and wide enough to include the width of each strip. A separate sheet is used for each strip. Strips are usually run in cardinal directions, either North and and South or East and West. In some instances it is necessary to follow other directions. Figures 22 and 23 show convenient note forms for each type of abney. Both note form and map strip read up from the bottom of the page, so that each is constantly oriented with the direction of travel.

A two-man crew is the economic unit for stripping. The head chainman is the compassman who prolongs the line of sight independent of the rear chainman, who is the topographer and who also may operate the abney. The compassman must be extremely careful to prolong a straight line, as the center line of the map strip itself is also a straight line. Irregular lines cannot be corrected. The topographer, in addition to following the procedure described previously for the abney, must sketch in contours and other detail directly in the field. He must know the horizontal distance to each contour along his strip so that he may plot it accurately. This is determined by use of the formula given in article 60 depending upon the abney-and-tape combination used. For the engineer's tape, this is stated as follows: The difference in elevation is equal to the horizontal distance times the abney reading divided by 100. By formula this is: $DE = \frac{HD \times abney}{100}$. However, the topographer desires to know the horizontal distance, so that he may plot it to scale on the strip. He has taken the abney reading, and he has the elevation of his station from which he determines the difference in elevation from there to the next contour. He also knows the contour interval. The formula then becomes: $HD = \frac{DE \times 100.}{abney}$ For example, suppose the topographer was at elevation 515, sketching in 20-foot contour intervals, and at this point his abney reading was plus 40. He wants to know how far it is from this point, which has already been plotted on his strip, to the 520-foot contour and to the 540-foot contour. Elevation difference to the 520-foot contour is 520 — 515 or 5 feet. Substituting in the formula: $HD = \frac{5 \times 100}{40} = 12\ 1/2$ feet. Therefore, to the scale of his map, he makes a mark on the center line of the strip just 12 1/2 feet from the previous point. The horizontal distance between contours is $\frac{20 \times 100}{40}$ or 50 feet. He then locates the 540-foot contour to scale just 50 feet beyond the 520-foot contour. A practiced topographer is able to solve this formula mentally as he progresses.

Having accurately plotted the contours on the strip center line between himself and the head chainman, he is ready to sketch them in to 330 feet on each side of the center line. He steps to the approximate position on the ground of each contour

and sketches in the form that each takes on the ground, giving heed to the characteristics of contours as he does so. If he cannot see out 330 feet to the right or left of him, he walks out to the side to determine the direction of the contour and to observe whether any streams, roads or other features fall within his strip. With practice he is able to judge with reasonable accuracy the angle the contour takes with his center line. His abney is a useful tool for determining slope variations and level lines.

The foregoing discussion was based on the premise that the contours were crossing the center line, but much of the time the center line will parallel a slope and fail to cross a contour. In this case, the same principle is used to find the horizontal distance to contours at right angles to the center line at each station along the line. Horizontal distance determined, the contours are accurately plotted on the map strip. The topographer then walks up or down the slope as necessary to get the "lay of the land".

From the original plat of the control lines, the topographer has determined the corrected elevations of his initial and final control points, and he has scaled off the length of his strip. When the crew has covered the predetermined length in the field, the next step is to locate the final control point and to "tie in". This means to establish the end of the strip with reference to the control point, thus closing the traverse and obtaining the errors of closure. This is done along cardinal directions, resolving the error of closure into three correctable components. The distance from strip to control point over or short along the center line is the plus or minus distance error. The distance at right angles to the strip is a right or left alignment or direction error. Elevations are carried along these two offsets to the control point itself. The difference between the corrected elevation of the control point and the one obtained after running the strip is the plus or minus elevation error. The computations are rechecked to eliminate the possibility of error from that source, and the three errors are recorded on the strip. At this point the field work for that strip is completed.

85. <u>Strip correction.</u> If there was an elevation error on the strip, and if it was within reasonable limits, having been satisfactorily determined that it did not occur all at one place,

it may then be assumed that it accumulated gradually. The elevation of each contour is then corrected by the proportionate formula in article 83: $Ca = \frac{a}{L} Ec$. The total distance covered (L) is determined from the field notes. It includes the length of the strip itself plus the length of all offsets. The distance to any contour (a) is scaled off the map strip. The error of closure (Ec) was recorded on the strip upon tying in to the control point.

The corrected elevation is written in opposite each contour on the strip. It is then necessary to insert new contours at the proper intervals between the originals. This is best explained by example. Suppose that the 520-foot contour has been corrected to read 516.2 feet, that the 540-foot contour has been corrected to 536.0 feet, and that the two contours are 100 feet apart. It is desired to relocate the 520-foot contour which obviously lies between these two elevations. This is done by proportion based on the principle of similar triangles. The horizontal distance to the new contour is to the horizontal distance between the old contours as the vertical distance to the new contour is to the vertical distance between the old contours. In this example, 520 -- 516.2 or 3.8 is the vertical distance to the new contour, and 536.0 -- 516.2 or 19.8 is the vertical distance between the original contours. Hence: $\frac{HD}{100} = \frac{3.8}{19.8}$, or $HD = \frac{3.8 \times 100}{19.8}$ or 19.2 feet, the horizontal distance from the original 520-foot contour to the corrected 520-foot contour. All the contours are corrected in this manner, each following the form of the original contours adjacent to it. If the field work is carefully done, very little correction is necessary and then only on the last few contours in the strip. Careful field work reduces the amount of office work and of course increases the accuracy of the map.

When the contours are corrected, the originals are erased from the strip, remaining features are refined (roads, streams, fences, etc.) and the strip itself is then finished ready for map assembly.

86. Plotting. Thus far, nothing has been stated about correcting for the distance and alignment errors. That is because these errors are not corrected. The strip is constructed to make the same error in transposing it to the map

sheet as was made on the ground when running the strip. The reason for this is obvious if a large error in direction is assumed. Instead of mapping a strip as was planned, the mapping crew is running off into an entirely different area, locating contours and detail for that area, and correcting these contours for that area only. It would thus be folly to shift the strip back onto the true cardinal line when plotting. The ground along the true line would look nothing like the map detail along that line. Unless the alignment errors on all the strips are in the same direction, there is obviously overlapping and gaps, but for small errors the gaps can be easily filled.

The distance error is likewise duplicated in plotting, by shifting the strip slightly at frequent intervals until the end of the strip is the same distance by scale from the control point as it was on the ground. For instance, the distance between two control points is one half mile, and the strip is one half mile long by scale. The topographer works under the assumption that no error is occurring, and when he finishes the strip, he has covered one half mile by scale on the sheet itself, but on the ground he ended up 100 feet short. He must by some means then shrink or foreshorten his strip sheet by 100 feet to get back to the terrain that he was mapping. While running the line he was gradually getting ahead on paper of what he was actually sketching on the ground.

The strip may be transposed onto the detail paper by several means. One method is to carbon the back of the strip with soft lead pencil and trace over the lines on the strip, thus transferring them to the map sheet. Another method is to place the strip under the map and trace through over a glass-topped table with a light underneath. Whatever method is used, the strip is first anchored at the base control point and tilted to make the alignment error. Then as it is traced it is shifted forward or backward to make the distance error. When this is done for each strip, the contours are connected, the rest of the details are refined, the map is inked, and its surface is then cleaned of construction lines. In connecting the contour lines, it must be realized that near the edge of each strip the accuracy may be low, one half a contour interval, and the contours frequently fail to meet. It must be remembered that the center line of each strip has been corrected to reasonable accuracy. The judgment of the topographer theoretically is the same in

sketching all his contours, so the error at the edge of each strip is somewhat the same. Therefore, two contours that do not meet are each moved an equal amount until they do coincide. This is likewise true for roads, streams, telephone lines, and other linear features.

87. Finishing the map. A map is incomplete until certain supplemental information is furnished. Minimum requirements are that it have a well-balanced title, direction arrows, scale and a legend.

The title states the type of a map it is, where the area is, when it was done, who made it, and under a heading, "Datum Description", how it was done. It is important to the map user how the controls were run, how the details were sketched, and if control and detail were corrected. For example, if contours were determined by aneroid barometer, the map would not suffice for accurate railroad location.

Direction arrows are necessary for orientation. Because lines were run by compass in the foregoing example, both magnetic and true north with declination should be shown. In addition to a scale expressed as an equation, it is desirable to have a graphical scale. The legend should define every sign and symbol shown on the map. It is usually balanced opposite the datum description. When these important details are completed the map is finished. An otherwise neat, accurate map is of little value if this supplemental data is poorly and carelessly rendered.

Section III. Problems.

1. Elevation of Station 8 + 63.5 on a mapping strip = 953.7 ft. Slope along the strip = +26%. What is the station where the 960 ft. contour crosses the strip center line?

Answer: 8 + 87.7

2. Strip length = 2650 ft. Elevation error in strip closure = +8 ft. Uncorrected station of 940 ft. contour = 15 + 63
Uncorrected station of 960 ft. contour = 16 + 72
Uncorrected station of 980 ft. contour = 17 + 75
What is the corrected station of the 960 ft. contour?

Answer: 16 + 98

3. Given: A map with scale: 1 inch = 400 ft., and contour interval = 25 ft.

a. Slope = 26%. What is the map distance between contours?

b. Map distance between contours = 1.3 inches. What is the % slope?

c. A stream, starting at one contour line, crosses 3 other contour lines in 2.8 inches on the map. What is the average slope of the stream?

d. A road is to be built on a uniform 11% grade beginning at a point on the 950 ft. contour and ending at a point 2610 ft. due North of the point of beginning. Elevation of the ending point is 1300 ft. What is the map length of the road?

e. What is the actual length of the road (slope distance)?

Answers: a. .24 inches
b. 4.8%
c. 6.7%
d. 8.0 inches
e. 3201 feet

4. A road built on a uniform 10% grade angles up a 19% slope. Contour interval is 20 feet. What is the horizontal distance between contours?

Answer: 200 feet

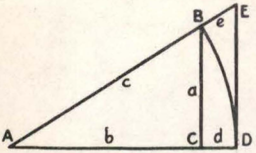
5. Horizontal distance between 2 contours = 100 ft. Elevation error on this part of the strip = -5 feet. 20-foot contour interval.

a. What is the horizontal shift required for the highest contour in order to correct the error?

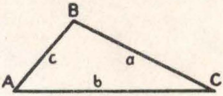
b. Is this shift uphill or downhill?

Answers: a. 25 feet
b. downhill

Appendix



RIGHT TRIANGLE



OBLIQUE TRIANGLE

SOLUTION OF RIGHT TRIANGLES.

$\sin A = \frac{a}{c} = \cos B$ $\qquad$ $\cos A = \frac{b}{c} = \sin B$

$\tan A = \frac{a}{b} = \cot B$ $\qquad$ $\cot A = \frac{b}{a} = \tan B$

$\sec A = \frac{c}{b} = \operatorname{cosec} B$ $\qquad$ $\operatorname{cosec} A = \frac{c}{a} = \sec B$

$\operatorname{vers} A = \frac{c-b}{c} = \frac{d}{c}$ $\qquad$ $\operatorname{exsec} A = \frac{e}{c}$

$a = c \sin A = b \tan A = c \cos B = b \cot B = \sqrt{(c+b)(c-b)}$

$b = c \cos A = a \cot A = c \sin B = a \tan B = \sqrt{(c+a)(c-a)} = c - c \operatorname{vers} A$

$d = c \operatorname{vers} A$ $\qquad$ $e = c \operatorname{exsec} A$

$$c = \frac{a}{\cos B} = \frac{b}{\sin B} = \frac{a}{\sin A} = \frac{b}{\cos A} = \frac{d}{\operatorname{vers} A} = \frac{e}{\operatorname{exsec} A} = b + b \operatorname{exsec} A$$

SOLUTION OF OBLIQUE TRIANGLES.

Given.	Sought.	Formulas.
A, B, a	b, c	$b = \frac{a}{\sin A} \sin B$, $\qquad c = \frac{a}{\sin A} \sin (A+B)$
A, a, b	B, c	$\sin B = \frac{\sin A}{a} \cdot b$, $\qquad c = \frac{a}{\sin A} \sin C.$
C, a, b	$A-B$	$\tan \frac{1}{2}(A-B) = \frac{a-b}{a+b} \tan \frac{1}{2}(A+B)$
a, b, c	A	If $s = \frac{1}{2}(a+b+c)$, $\sin \frac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{bc}}$
		$\cos \frac{1}{2} A = \sqrt{\frac{s(s-a)}{bc}}$; $\tan \frac{1}{2} A = \sqrt{\frac{(s-b)(s-c)}{s(s-a)}}$
		$\sin A = \frac{2\sqrt{s(s-a)(s-b)(s-c)}}{bc}$;
		$\operatorname{vers} A = \frac{2(s-b)(s-c)}{bc}$
	area	$\text{area} = \sqrt{s(s-a)(s-b)(s-c)}$
A, B, C, a	area	$\text{area} = \frac{a^2 \sin B \sin C}{2 \sin A}$
C, a, b	area	$\text{area} = \frac{1}{2} a b \sin C.$

Percent	Degrees	Percent	Degrees	Percent	Degrees	Percent	Degrees
	° ′		° ′		° ′		° ′
1	34	26	14 34	51	27 01	76	37 14
2	1 09	27	15 07	52	27 28	77	37 36
3	1 43	28	15 39	53	27 55	78	37 57
4	2 17	29	16 10	54	28 22	79	38 19
5	2 52	30	16 42	55	28 49	80	38 40
6	3 26	31	17 13	56	29 15	81	39 00
7	4 00	32	17 45	57	29 41	82	39 21
8	4 34	33	18 16	58	30 07	83	39 42
9	5 09	34	18 47	59	30 32	84	40 02
10	5 43	35	19 17	60	30 58	85	40 22
11	6 17	36	19 48	61	31 23	86	40 42
12	6 51	37	20 18	62	31 48	87	41 01
13	7 24	38	20 48	63	32 13	88	41 21
14	7 58	39	21 18	64	32 37	89	41 40
15	8 32	40	21 48	65	33 01	90	41 59
16	9 05	41	22 18	66	33 25	91	42 18
17	9 39	42	22 47	67	33 49	92	42 37
18	10 12	43	23 16	68	34 13	93	42 55
19	10 45	44	23 45	69	34 36	94	43 14
20	11 19	45	24 14	70	35 00	95	43 32
21	11 52	46	24 42	71	35 22	96	43 50
22	12 24	47	25 10	72	35 45	97	44 08
23	12 57	48	25 38	73	36 08	98	44 25
24	13 30	49	26 06	74	36 30	99	44 43
25	14 02	50	26 34	75	36 52	100	45 00

Table 1a Equivalents of percents and degrees.

Degrees	Percent	Degrees	Percent	Degrees	Percent	Degrees	Percent
1	1.74	16	28.67	31	60.09	46	103.55
2	3.49	17	30.57	32	62.49	47	107.24
3	5.24	18	32.49	33	64.94	48	111.06
4	6.99	19	34.43	34	67.45	49	115.04
5	8.75	20	36.40	35	70.02	50	119.18
6	10.51	21	38.39	36	72.65	51	123.49
7	12.28	22	40.40	37	75.35	52	127.99
8	14.05	23	42.45	38	78.13	53	132.70
9	15.84	24	44.52	39	80.98	54	137.64
10	17.63	25	46.63	40	83.91	55	142.81
11	19.44	26	48.77	41	86.93	56	148.26
12	21.26	27	50.95	42	90.04	57	153.99
13	23.09	28	53.17	43	93.25	58	160.03
14	24.93	29	55.43	44	96.57	59	166.43
15	26.80	30	57.73	45	100.00	60	173.20

Table 1b Equivalents of degrees in percents.

Tables 1, 2, and 3. Abney conversion tables.

Percent	Topographic	Percent	Topographic	Percent	Topographic	Percent	Topographic
1	0.66	26	17.16	51	33.66	76	50.16
2	1.32	27	17.82	52	34.32	77	50.82
3	1.98	28	18.48	53	34.98	78	51.48
4	2.64	29	19.14	54	35.64	79	52.14
5	3.30	30	19.80	55	36.30	80	52.80
6	3.96	31	20.46	56	36.96	81	53.46
7	4.62	32	21.12	57	37.62	82	54.12
8	5.28	33	21.78	58	38.28	83	54.78
9	5.94	34	22.44	59	38.94	84	55.44
10	6.60	35	23.10	60	39.60	85	56.10
11	7.26	36	23.76	61	40.26	86	56.76
12	7.92	37	24.42	62	40.92	87	57.42
13	8.58	38	25.08	63	41.58	88	58.08
14	9.24	39	25.74	64	42.24	89	58.74
15	9.90	40	26.40	65	42.90	90	59.40
16	10.56	41	27.06	66	43.56	91	60.06
17	11.22	42	27.72	67	44.22	92	60.72
18	11.88	43	28.38	68	44.88	93	61.38
19	12.54	44	29.04	69	45.54	94	62.04
20	13.20	45	29.70	70	46.20	95	62.70
21	13.86	46	30.36	71	46.86	96	63.36
22	14.52	47	31.02	72	47.52	97	64.02
23	15.18	48	31.68	73	48.18	98	64.68
24	15.84	49	32.34	74	48.84	99	65.34
25	16.50	50	33.00	75	49.50	100	66.00

Table 2a Equivalents of percents in topographic graduations.

Topographic	Percent	Topographic	Percent	Topographic	Percent	Topographic	Percent
1	1.51	21	31.81	41	62.11	61	92.41
2	3.03	22	33.33	42	63.63	62	93.93
3	4.54	23	34.84	43	65.14	63	95.44
4	6.06	24	36.36	44	66.66	64	96.96
5	7.57	25	37.87	45	68.17	65	98.47
6	9.09	26	39.39	46	69.69	66	99.99
7	10.60	27	40.90	47	71.20	67	101.50
8	12.12	28	42.42	48	72.72	68	103.02
9	13.63	29	43.93	49	74.23	69	104.53
10	15.15	30	45.45	50	75.75	70	106.05
11	16.67	31	46.97	51	77.27	71	107.57
12	18.18	32	48.48	52	78.78	72	109.08
13	19.70	33	50.00	53	80.30	73	110.60
14	21.21	34	51.51	54	81.81	74	112.11
15	22.73	35	53.03	55	83.33	75	113.63
16	24.24	36	54.54	56	84.84	76	115.14
17	25.76	37	56.06	57	86.36	77	116.66
18	27.27	38	57.57	58	87.87	78	118.17
19	28.79	39	59.09	59	89.39	79	119.69
20	30.30	40	60.60	60	90.90	80	121.20

Table 2b Equivalents of topographic graduations in percents.

Degrees	Topographic	Degrees	Topographic	Degrees	Topographic	Degrees	Topographic
1	1.15	16	18.93	31	39.66	46	68.34
2	2.30	17	20.18	32	41.24	47	70.78
3	3.46	18	21.44	33	42.86	48	73.30
4	4.62	19	22.73	34	44.52	49	75.92
5	5.77	20	24.02	35	46.21	50	78.66
6	6.94	21	25.33	36	47.95	51	81.50
7	8.10	22	26.67	37	49.73	52	84.48
8	9.28	23	28.02	38	51.57	53	87.58
9	10.45	24	29.39	39	53.45	54	90.84
10	11.64	25	30.78	40	55.38	55	94.26
11	12.83	26	32.19	41	57.37	56	97.85
12	14.03	27	33.63	42	59.43	57	101.63
13	15.24	28	35.09	43	61.55	58	105.62
14	16.46	29	36.58	44	63.74	59	109.84
15	17.68	30	38.11	45	66.00	60	114.32

Table 3a Equivalents of degrees in topographic graduations.

Topographic	Degrees	Topographic	Degrees	Topographic	Degrees	Topographic	Degrees
	° ′		° ′		° ′		° ′
1	0 52	21	17 39	41	31 51	61	42 45
2	1 44	22	18 26	42	32 28	62	43 13
3	2 36	23	19 13	43	33 05	63	43 40
4	3 28	24	19 59	44	33 41	64	44 07
5	4 20	25	20 45	45	34 17	65	44 34
6	5 12	26	21 30	46	34 53	66	45 00
7	6 04	27	22 15	47	35 27	67	45 26
8	6 55	28	22 50	48	36 02	68	45 51
9	7 46	29	23 43	49	36 35	69	46 16
10	8 37	30	24 27	50	37 09	70	46 41
11	9 28	31	25 10	51	37 42	71	47 05
12	10 18	32	25 52	52	38 14	72	47 29
13	11 08	33	26 34	53	38 46	73	47 53
14	11 59	34	27 15	54	39 17	74	48 16
15	12 48	35	27 56	55	39 48	75	48 39
16	13 3[illegible]	36	28 37	56	40 19	76	49 02
17	14 27	37	29 17	57	40 49	77	49 24
18	15 15	38	29 56	58	41 19	78	49 46
19	16 04	39	30 35	59	41 48	79	50 07
20	16 51	40	31 13	60	42 16	80	50 29

Table 3b Equivalents of topographic graduations in degrees.

1

7/5 x.40 .08

20.81 20.90 .16 20.81

Slope distance in links	Topographic															
	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80
2	2.0	2.0	2.0	1.9	1.9	1.8	1.8	1.7	1.7	1.6	1.5	1.5	1.4	1.4	1.3	1.3
4	4.0	4.0	4.0	3.8	3.7	3.6	3.5	3.4	3.3	3.2	3.1	3.0	2.8	2.7	2.6	2.5
6	6.0	5.9	5.9	5.7	5.6	5.5	5.3	5.1	5.0	4.8	4.6	4.4	4.3	4.1	4.0	3.8
8	8.0	7.9	7.8	7.7	7.5	7.3	7.1	6.8	6.6	6.4	6.1	5.9	5.7	5.5	5.3	5.1
10	10.0	9.9	9.8	9.6	9.4	9.1	8.8	8.6	8.3	8.0	7.7	7.4	7.1	6.9	6.6	6.4
12	12.0	11.9	11.7	11.5	11.2	10.9	10.6	10.3	9.9	9.6	9.2	8.9	8.5	8.2	7.9	7.6
14	14.0	13.8	13.7	13.4	13.1	12.7	12.4	12.0	11.6	11.2	10.8	10.4	10.0	9.6	9.2	8.9
16	16.0	15.8	15.6	15.3	15.0	14.6	14.1	13.7	13.2	12.8	12.3	11.8	11.4	11.0	10.6	10.2
18	17.9	17.8	17.6	17.2	16.8	16.4	15.9	15.4	14.9	14.3	13.8	13.3	12.8	12.3	11.9	11.5
20	19.9	19.8	19.5	19.1	18.7	18.2	17.7	17.1	16.5	15.9	15.4	14.8	14.2	13.7	13.2	12.7
22	21.9	21.8	21.5	21.0	20.6	20.0	19.4	18.8	18.2	17.5	16.9	16.3	15.7	15.1	14.5	14.0
24	23.9	23.7	23.4	23.0	22.4	21.8	21.2	20.5	19.8	19.1	18.4	17.8	17.1	16.5	15.9	15.3
26	25.9	25.7	25.4	24.9	24.3	23.7	23.0	22.2	21.5	20.7	20.0	19.2	18.5	17.8	17.2	16.5
28	27.9	27.7	27.3	26.8	26.2	25.5	24.7	23.9	23.1	22.3	21.5	20.7	19.9	19.2	18.5	17.8
30	29.9	29.7	29.3	28.7	28.1	27.3	26.5	25.7	24.8	23.9	23.0	22.2	21.4	20.6	19.8	19.1
32	31.9	31.6	31.2	30.6	29.9	29.1	28.3	27.4	26.4	25.5	24.6	23.7	22.8	22.0	21.1	20.4
34	33.9	33.6	33.2	32.5	31.8	31.0	30.0	29.1	28.1	27.1	26.1	25.2	24.2	23.3	22.5	21.6
36	35.9	35.6	35.1	34.5	33.7	32.8	31.8	30.8	29.7	28.7	27.7	26.6	25.6	24.7	23.8	22.9
38	37.9	37.6	37.1	36.4	35.5	34.6	33.6	32.5	31.4	30.3	29.2	28.1	27.1	26.1	25.1	24.2
40	39.9	39.5	39.0	38.3	37.4	36.4	35.3	34.2	33.0	31.9	30.7	29.6	28.5	27.4	26.4	25.5
42	41.9	41.5	41.0	40.2	39.3	38.2	37.0	35.9	34.7	33.5	32.3	31.1	29.9	28.8	27.7	26.7
44	43.9	43.5	42.9	42.1	41.1	40.1	38.9	37.6	36.4	35.1	33.8	32.6	31.3	30.2	29.1	28.0
46	45.9	45.5	44.9	44.0	43.0	41.9	40.6	39.3	38.0	36.7	35.3	34.0	32.8	31.6	30.4	29.3
48	47.9	47.5	46.8	45.9	44.9	43.7	42.4	41.0	39.7	38.3	36.9	35.3	34.2	32.9	31.7	30.5
50	49.9	49.4	48.8	47.9	46.8	45.5	44.2	42.8	41.3	39.9	38.4	37.0	35.6	34.3	33.0	31.8
52	51.9	51.4	50.7	49.8	48.6	47.3	45.9	44.5	43.0	41.4	39.9	38.5	37.0	35.7	34.4	33.1
54	53.8	53.4	52.7	51.7	50.5	49.2	47.7	46.2	44.6	43.0	41.5	40.0	38.5	37.0	35.7	34.4
56	55.8	55.4	54.6	53.6	52.4	51.0	49.5	47.9	46.3	44.6	43.0	41.4	39.9	38.4	37.0	35.6
58	57.8	57.3	56.6	55.5	54.2	52.8	51.2	49.6	47.9	46.2	44.6	42.9	41.3	39.8	38.3	36.9
60	59.8	59.3	58.5	57.4	56.1	54.6	53.0	51.3	49.6	47.8	46.1	44.4	42.7	41.2	39.6	38.2
62	61.8	61.3	60.5	50.3	58.0	56.4	54.8	53.0	51.2	49.4	47.6	45.9	44.2	42.5	41.0	39.5
64	63.8	63.3	62.4	61.2	59.9	58.3	56.5	54.7	52.9	51.0	49.2	47.4	45.6	43.9	42.3	40.7
66	65.8	65.3	64.4	63.2	61.7	60.1	58.3	56.4	54.5	52.6	50.7	48.8	47.0	45.3	43.6	42.0
68	67.8	67.2	66.3	65.1	63.6	61.9	60.1	58.1	56.2	54.2	52.2	50.3	48.4	46.4	44.9	43.3
70	69.8	69.2	68.3	67.0	65.5	63.7	61.8	59.9	57.8	55.8	53.8	51.8	49.9	48.0	46.2	44.5
72	71.8	71.2	70.2	68.9	67.3	65.5	63.6	61.6	59.5	57.4	55.3	53.3	51.3	49.4	47.6	45.8
74	73.8	73.2	72.2	70.8	69.2	67.4	65.4	63.3	61.1	59.0	56.8	54.8	52.7	50.8	48.9	47.1
76	75.8	75.1	74.1	72.7	71.1	69.2	67.1	65.0	62.8	60.6	58.4	56.2	54.1	52.1	50.2	48.4
78	77.8	77.1	76.1	74.6	72.9	71.0	68.9	66.7	64.4	62.2	59.9	57.7	55.6	53.5	51.5	49.6
80	79.8	79.1	78.0	76.6	74.8	72.8	70.7	68.4	66.1	63.8	61.5	59.2	57.0	54.9	52.9	50.9
82	81.8	81.1	80.0	78.5	76.6	74.6	72.4	70.1	67.8	65.4	63.0	60.7	58.4	56.3	54.2	52.2
84	83.8	81.3	81.9	80.4	78.6	76.5	74.2	71.8	69.4	67.0	64.5	62.2	59.8	57.6	55.5	53.5
86	85.8	85.0	83.9	82.3	80.4	78.3	76.0	73.5	71.1	68.5	66.1	63.6	61.3	59.0	56.8	54.7
88	87.7	87.0	85.8	84.2	82.3	80.1	77.7	75.3	72.7	70.1	67.6	65.1	62.7	60.4	58.1	56.0
90	89.7	89.0	87.8	86.1	84.2	81.9	79.5	77.0	74.4	71.7	69.1	66.6	64.1	61.7	59.5	57.3
92	91.7	91.0	89.7	88.0	86.0	83.8	81.3	78.7	76.0	73.3	70.7	68.1	65.5	63.1	60.8	58.5
94	93.7	92.9	91.7	90.0	87.9	85.6	83.0	80.4	77.7	74.9	72.2	69.6	67.0	64.7	62.1	59.8
96	95.7	94.9	93.6	91.9	89.8	87.4	84.8	82.1	79.3	76.5	73.7	71.0	68.4	65.9	63.4	61.1
98	97.7	96.9	95.6	93.8	91.6	89.2	86.6	83.8	81.0	78.1	75.3	72.5	69.8	67.2	64.7	62.4
100	99.7	98.9	97.5	95.7	93.5	91.0	88.2	85.5	82.6	79.7	76.8	74.0	71.2	68.6	66.1	63.6

Table 4. Conversion of slope distance to horizontal distance for various readings on the topographic abney.

	6%		7%		8%		9%		10%	
	Angle	3°26	Angle	4°00	Angle	4°34	Angle	5°09	Angle	5°43
40	39.9	2.4	39.9	2.8	39.9	3.2	39.8	3.6	39.8	4.0
50	49.9	3.0	49.9	3.5	49.8	4.0	49.8	4.5	49.8	5.0
60	59.9	3.6	59.9	4.2	59.8	4.8	59.8	5.4	59.7	6.0
70	69.9	4.2	69.8	4.9	69.8	5.6	69.7	6.3	69.7	7.0
80	79.9	4.8	79.8	5.6	79.7	6.4	79.7	7.2	79.6	8.0
90	89.8	5.4	89.8	6.3	89.7	7.2	89.6	8.1	89.6	9.0
100	99.8	6.0	99.8	7.0	99.7	8.0	99.6	9.0	99.5	10.0
110	109.8	6.6	109.7	7.7	109.7	8.8	109.6	9.9	109.5	11.0
120	119.8	7.2	119.7	8.4	119.6	9.6	119.5	10.8	119.4	12.0
130	129.8	7.8	129.7	9.1	129.6	10.4	129.5	11.7	129.4	12.9
140	139.7	8.4	139.7	9.8	139.6	11.1	139.4	12.6	139.3	13.9
150	149.7	9.0	149.6	10.5	149.5	11.9	149.4	13.5	149.3	14.9
160	159.7	9.6	159.6	11.2	159.5	12.7	159.4	14.4	159.2	15.9
170	169.7	10.2	169.6	11.9	169.5	13.5	169.3	15.3	169.2	16.9
180	179.7	10.8	179.6	12.6	179.4	14.3	179.3	16.2	179.1	17.9
190	189.7	11.4	189.5	13.3	189.4	15.1	189.2	17.1	189.1	18.9
200	199.6	12.0	199.5	14.0	199.4	15.9	199.2	18.0	199.0	19.9
210	209.6	12.6	209.5	14.6	209.3	16.7	209.2	18.8	209.0	20.9
220	219.6	13.2	219.5	15.3	219.3	17.5	219.1	19.7	218.9	21.9
230	229.6	13.8	229.4	16.0	229.3	18.3	229.1	20.6	228.9	22.9
240	239.6	14.4	239.4	16.7	239.2	19.1	239.0	21.5	238.8	23.9
250	249.6	15.0	249.4	17.4	249.2	19.9	249.0	22.4	248.8	24.9
260	259.5	15.6	259.4	18.1	259.2	20.7	258.9	23.3	258.7	25.9
270	269.5	16.2	269.3	18.8	269.1	21.5	268.9	24.2	268.7	26.9
280	279.5	16.8	279.3	19.5	279.1	22.3	278.9	25.1	278.6	27.9
290	289.5	17.4	289.3	20.2	289.1	23.1	288.8	26.0	288.6	28.9
300	299.5	18.0	299.3	20.9	299.0	23.9	298.8	26.9	298.5	29.9

	11%		12%		13%		14%		15%	
	Angle	6°17	Angle	6°51	Angle	7°24	Angle	7°58	Angle	8°32
40	39.8	4.4	39.7	4.8	39.7	5.2	39.6	5.5	39.6	5.9
50	49.7	5.5	49.6	6.0	49.6	6.4	49.5	6.9	49.4	7.4
60	59.6	6.6	59.6	7.2	59.5	7.7	59.4	8.3	59.3	8.9
70	69.6	7.7	69.5	8.3	69.4	9.0	69.3	9.7	69.2	10.4
80	79.5	8.8	79.4	9.5	79.3	10.3	79.2	11.1	79.1	11.9
90	89.5	9.9	89.4	10.7	89.3	11.6	89.1	12.5	89.0	13.4
100	99.4	10.9	99.3	11.9	99.2	12.9	99.0	13.9	98.9	14.8
110	109.3	12.0	109.2	13.1	109.1	14.2	108.9	15.2	108.8	16.3
120	119.3	13.1	119.1	14.3	119.0	15.5	118.8	16.6	118.7	17.8
130	129.2	14.2	129.1	15.5	128.9	16.7	128.7	18.0	128.6	19.3
140	139.2	15.3	139.0	16.7	138.8	18.0	138.6	19.4	138.5	20.8
150	149.1	16.4	148.9	17.9	148.8	19.3	148.6	20.8	148.3	22.3
160	159.1	17.5	158.9	19.1	158.7	20.6	158.5	22.2	158.2	23.7
170	169.0	18.6	168.8	20.3	168.6	21.9	168.4	23.6	168.1	25.2
180	178.9	19.7	178.7	21.5	178.5	23.2	178.3	24.9	178.0	26.7
190	188.9	20.8	188.6	22.7	188.4	24.5	188.2	26.3	187.9	28.2
200	198.8	21.9	198.6	23.9	198.3	25.8	198.1	27.7	197.8	29.7
210	208.7	23.0	208.5	25.0	208.3	27.0	208.0	29.1	207.7	31.2
220	218.7	24.1	218.4	26.2	218.2	28.3	217.9	30.5	217.6	32.6
230	228.6	25.2	228.4	27.4	228.1	29.6	227.8	31.9	227.5	34.1
240	238.6	26.3	238.3	28.6	238.0	30.9	237.7	33.3	237.3	35.6
250	248.5	27.4	248.2	29.8	247.9	32.2	247.6	34.7	247.2	37.1
260	258.4	28.5	258.1	31.0	257.8	33.5	257.5	36.0	257.1	38.6
270	268.4	29.6	268.1	32.2	267.8	34.8	267.4	37.4	267.0	40.1
280	278.3	30.6	278.0	33.4	277.7	36.1	277.3	38.8	276.9	41.5
290	288.3	31.7	287.9	34.6	287.6	37.4	287.2	40.2	286.8	43.0
300	298.2	32.8	297.9	35.8	297.5	38.6	297.1	41.6	296.7	44.5

	16%		17%		18%		19%		20%	
	Angle	9°05	Angle	9°39	Angle	10°12	Angle	10°45	Angle	11°19
40	39.5	6.3	39.4	6.7	39.4	7.1	39.3	7.5	39.2	7.8
50	49.4	7.9	49.3	8.4	49.2	8.9	49.1	9.3	49.0	9.8
60	59.2	9.5	59.2	10.1	59.1	10.6	58.9	11.2	58.8	11.8
70	69.1	11.1	69.0	11.7	68.9	12.4	68.8	13.1	68.6	13.7
80	79.0	12.6	78.9	13.4	78.7	14.2	78.6	14.9	78.4	15.7
90	88.9	14.2	88.7	15.1	88.6	15.9	88.4	16.8	88.3	17.7
100	98.7	15.8	98.6	16.8	98.4	17.7	98.2	18.7	98.1	19.6
110	108.6	17.4	108.4	18.4	108.3	19.5	108.1	20.5	107.9	21.6
120	118.5	18.9	118.3	20.1	118.1	21.2	117.9	22.4	117.7	23.5
130	128.4	20.5	128.2	21.8	127.9	23.0	127.7	24.2	127.5	25.5
140	138.2	22.1	138.0	23.5	137.8	24.8	137.5	26.1	137.3	27.5
150	148.1	23.7	147.9	25.1	147.6	26.6	147.4	28.0	147.1	29.4
160	158.0	25.3	157.7	26.8	157.5	28.3	157.2	29.8	156.9	31.4
170	167.9	26.8	167.6	28.5	167.3	30.1	167.0	31.7	166.7	33.4
180	177.7	28.4	177.5	30.2	177.2	31.9	176.8	33.6	176.5	35.3
190	187.6	30.0	187.3	31.8	187.0	33.6	186.7	35.4	186.3	37.3
200	197.5	31.6	197.2	33.5	196.8	35.4	196.5	37.3	196.1	39.2
210	207.4	33.2	207.0	35.2	206.7	37.2	206.3	39.2	205.9	41.2
220	217.2	34.7	216.9	36.9	216.5	39.0	216.1	41.0	215.7	43.2
230	227.1	36.3	226.7	38.6	226.4	40.7	226.0	42.9	225.5	45.1
240	237.0	37.9	236.6	40.2	236.2	42.5	235.8	44.8	235.3	47.1
250	246.9	39.5	246.5	41.9	246.1	44.3	245.6	46.6	245.1	49.1
260	256.7	41.0	256.3	43.6	255.9	46.0	255.4	48.5	254.9	51.0
270	266.6	42.6	266.2	45.3	265.7	47.8	265.3	50.4	264.8	53.0
280	276.5	44.2	276.0	46.9	275.6	49.6	275.1	52.2	274.6	54.9
290	286.4	45.8	285.9	48.6	285.4	51.4	284.9	54.1	284.4	56.9
300	296.2	47.4	295.8	50.3	295.3	53.1	294.7	56.0	294.2	58.9

Compiled by Lester Calder

Table 5. Calder slope reduction tables for the per cent abney.

	21%		22%		23%		24%		25%	
	Angle 11°52		Angle 12°24		Angle 12°57		Angle 13°30		Angle 14°02	
40	39.1	8.2	39.1	8.6	39.0	9.0	38.9	9.3	38.8	9.7
50	48.9	10.3	48.8	10.7	48.7	11.2	48.6	11.7	48.5	12.1
60	58.7	12.3	58.6	12.9	58.5	13.4	58.3	14.0	58.2	14.5
70	68.5	14.4	68.4	15.0	68.2	15.7	68.1	16.3	67.9	17.0
80	78.3	16.5	78.1	17.2	78.0	17.9	77.8	18.7	77.6	19.4
90	88.1	18.5	87.9	19.3	87.7	20.2	87.5	21.0	87.3	21.8
100	97.9	20.6	97.7	21.5	97.5	22.4	97.2	23.3	97.0	24.2
110	107.6	22.6	107.4	23.6	107.2	24.7	107.0	25.7	106.7	26.7
120	117.4	24.7	117.2	25.8	116.9	26.9	116.7	28.0	116.4	29.1
130	127.2	26.7	127.0	27.9	126.7	29.1	126.4	30.3	126.1	31.5
140	137.0	28.8	136.7	30.1	136.4	31.4	136.1	32.7	135.8	33.9
150	146.8	30.8	146.5	32.2	146.2	33.6	145.9	35.0	145.5	36.4
160	156.6	32.9	156.3	34.4	155.9	35.9	155.6	37.4	155.2	38.8
170	166.4	35.0	166.0	36.5	165.7	38.1	165.3	39.7	164.9	41.2
180	176.2	37.0	175.8	38.7	175.4	40.3	175.0	42.0	174.6	43.6
190	185.9	39.1	185.6	40.8	185.2	42.6	184.8	44.4	184.3	46.1
200	195.7	41.1	195.3	42.9	194.9	44.8	194.5	46.7	194.0	48.5
210	205.5	43.2	205.1	45.1	204.7	47.1	204.2	49.0	203.7	50.9
220	215.3	45.2	214.9	47.2	214.4	49.3	213.9	51.4	213.4	53.3
230	225.1	47.3	224.6	49.4	224.2	51.5	223.6	53.7	223.1	55.8
240	234.9	49.4	234.4	51.5	233.9	53.8	233.4	56.0	232.8	58.2
250	244.7	51.4	244.2	53.7	243.6	56.0	243.1	58.4	242.5	60.6
260	254.4	53.5	253.9	55.8	253.4	58.3	252.8	60.7	252.2	63.0
270	264.2	55.5	263.7	58.0	263.1	60.5	262.5	63.0	261.9	65.5
280	274.0	57.6	273.5	60.1	272.9	62.7	272.3	65.4	271.6	67.9
290	283.8	59.6	283.2	62.3	282.6	65.0	282.0	67.7	281.3	70.3
300	293.6	61.7	293.0	64.4	292.4	67.2	291.7	70.0	291.0	72.7

	26%		27%		28%		29%		30%	
	Angle 14°34		Angle 15°07		Angle 15°39		Angle 16°10		Angle 16°42	
40	38.7	10.1	38.6	10.4	38.5	10.8	38.4	11.1	38.3	11.5
50	48.4	12.6	48.3	13.0	48.1	13.5	48.0	13.9	47.9	14.4
60	58.1	15.1	57.9	15.6	57.8	16.2	57.6	16.7	57.5	17.2
70	67.8	17.6	67.6	18.3	67.4	18.9	67.2	19.5	67.0	20.1
80	77.4	20.1	77.2	20.9	77.0	21.6	76.8	22.3	76.6	23.0
90	87.1	22.6	86.9	23.5	86.7	24.3	86.4	25.1	86.2	25.9
100	96.8	25.2	96.5	26.1	96.3	27.0	96.0	27.8	95.8	28.7
110	106.5	27.7	106.2	28.7	105.9	29.7	105.7	30.6	105.4	31.6
120	116.1	30.2	115.8	31.3	115.6	32.4	115.3	33.4	114.9	34.5
130	125.8	32.7	125.5	33.9	125.2	35.1	124.9	36.2	124.5	37.4
140	135.5	35.2	135.2	36.5	134.8	37.8	134.5	39.0	134.1	40.2
150	145.2	37.7	144.8	39.1	144.4	40.5	144.1	41.8	143.7	43.1
160	154.9	40.2	154.5	41.7	154.1	43.2	153.7	44.5	153.3	46.0
170	164.5	42.8	164.1	44.3	163.7	45.9	163.3	47.3	162.8	48.9
180	174.2	45.3	173.8	46.9	173.3	48.6	172.9	50.1	172.4	51.7
190	183.9	47.8	183.4	49.5	183.0	51.3	182.5	52.9	182.0	54.6
200	193.6	50.3	193.1	52.2	192.6	54.0	192.1	55.7	191.6	57.5
210	203.3	52.8	202.7	54.8	202.2	56.6	201.7	58.5	201.1	60.3
220	212.9	55.3	212.4	57.4	211.8	59.3	211.3	61.3	210.7	63.2
230	222.6	57.8	222.0	60.0	221.5	62.0	220.9	64.0	220.3	66.1
240	232.3	60.4	231.7	62.6	231.1	64.7	230.5	66.8	229.9	69.0
250	242.0	62.9	241.4	65.2	240.7	67.4	240.1	69.6	239.5	71.8
260	251.6	65.4	251.0	67.8	250.4	70.1	249.7	72.4	249.0	74.7
270	261.3	67.9	260.7	70.4	260.0	72.8	259.3	75.2	258.6	77.6
280	271.0	70.4	270.3	73.0	269.6	75.5	268.9	78.0	268.2	80.5
290	280.7	72.9	280.0	75.6	279.2	78.2	278.5	80.7	277.8	83.3
300	290.4	75.5	289.6	78.2	288.9	80.9	288.1	83.5	287.3	86.2

	31%		32%		33%		34%		35%	
	Angle 17°13		Angle 17°45		Angle 18°16		Angle 18°47		Angle 19°17	
40	38.2	11.8	38.1	12.2	38.0	12.5	37.9	12.9	37.8	13.2
50	47.8	14.8	47.6	15.2	47.5	15.7	47.3	16.1	47.2	16.5
60	57.3	17.8	57.1	18.3	57.0	18.8	56.8	19.3	56.6	19.8
70	66.9	20.7	66.7	21.3	66.5	21.9	66.3	22.5	66.1	23.1
80	76.4	23.7	76.2	24.4	76.0	25.1	75.7	25.8	75.5	26.4
90	86.0	26.6	85.7	27.4	85.5	28.2	85.2	29.0	85.0	29.7
100	95.5	29.6	95.2	30.5	95.0	31.3	94.7	32.2	94.4	33.0
110	105.1	32.6	104.8	33.5	104.5	34.5	104.1	35.4	103.8	36.3
120	114.6	35.5	114.3	36.6	114.0	37.6	113.6	38.6	113.3	39.6
130	124.2	38.5	123.8	39.6	123.4	40.7	123.1	41.9	122.7	42.9
140	133.7	41.4	133.3	42.7	132.9	43.9	132.5	45.1	132.1	46.2
150	143.3	44.4	142.9	45.7	142.4	47.0	142.0	48.3	141.6	49.5
160	152.8	47.4	152.4	48.8	151.9	50.2	151.5	51.5	151.0	52.8
170	162.4	50.3	161.9	51.8	161.4	53.3	160.9	54.7	160.5	56.1
180	171.9	53.3	171.4	54.9	170.9	56.4	170.4	56.0	169.9	59.4
190	181.5	56.2	181.0	57.9	180.4	59.6	179.9	61.2	179.3	62.7
200	191.0	59.2	190.5	61.0	189.9	62.7	189.3	64.4	188.8	66.0
210	200.6	62.2	200.0	64.0	199.4	65.8	198.8	67.6	198.2	69.4
220	210.1	65.1	209.5	67.1	208.9	69.0	208.3	70.8	207.7	72.7
230	219.7	68.1	219.1	70.1	218.4	72.1	217.8	74.1	217.1	76.0
240	229.2	71.0	228.6	73.2	227.9	75.2	227.2	77.3	226.5	79.3
250	238.8	74.0	238.1	76.2	237.4	78.4	236.7	80.5	236.0	82.6
260	248.3	77.0	247.6	79.3	246.9	81.5	246.2	83.7	245.4	85.9
270	257.9	79.9	257.1	82.3	256.4	84.6	255.6	86.9	254.9	89.2
280	267.5	82.9	266.7	85.4	265.9	87.8	265.1	90.2	264.3	92.5
290	277.0	85.8	276.2	88.4	275.4	90.9	274.6	93.4	273.7	95.8
300	286.6	88.8	285.7	91.5	284.9	94.0	284.0	96.6	283.2	99.1

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	36%		37%		38%		39%		40%	
	Angle 19°48		Angle 20°18		Angle 20°48		Angle 21°18		Angle 21°48	
40	37.6	13.5	37.5	13.9	37.4	14.2	37.3	14.5	37.1	14.9
50	47.0	16.9	46.9	17.3	46.7	17.8	46.6	18.2	46.4	18.6
60	56.5	20.3	56.3	20.8	56.1	21.3	55.9	21.8	55.7	22.3
70	65.9	23.7	65.7	24.3	65.4	24.9	65.2	25.4	65.0	26.0
80	75.3	27.1	75.0	27.8	74.8	28.4	74.5	29.1	74.3	29.7
90	84.7	30.5	84.4	31.2	84.1	32.0	83.9	32.7	83.6	33.4
100	94.1	33.9	93.8	34.7	93.5	35.5	93.2	36.3	92.8	37.1
110	103.5	37.3	103.2	38.2	102.8	39.1	102.5	40.0	102.1	40.9
120	112.9	40.6	112.5	41.6	112.2	42.6	111.8	43.6	111.4	44.6
130	122.3	44.0	121.9	45.1	121.5	46.2	121.1	47.2	120.7	48.3
140	131.7	47.4	131.3	48.6	130.9	49.7	130.4	50.9	130.0	52.0
150	141.1	50.8	140.7	52.0	140.2	53.3	139.8	54.5	139.3	55.7
160	150.5	54.2	150.1	55.5	149.6	56.8	149.1	58.1	148.6	59.4
170	159.9	57.6	159.4	59.0	158.9	60.4	158.4	61.8	157.8	63.1
180	169.4	61.0	168.8	62.4	168.3	63.9	167.7	65.4	167.1	66.8
190	178.8	64.4	178.2	65.9	177.6	67.5	177.0	69.0	176.4	70.6
200	188.2	67.7	187.6	69.4	187.0	71.0	186.3	72.7	185.7	74.3
210	197.6	71.1	197.0	72.9	196.3	74.6	195.7	76.3	195.0	78.0
220	207.0	74.5	206.3	76.3	205.7	78.1	205.0	79.9	204.3	81.7
230	216.4	77.9	215.7	79.8	215.0	81.7	214.3	83.5	213.6	85.4
240	225.8	81.3	225.1	83.3	224.4	85.2	223.6	87.2	222.8	89.1
250	235.2	84.7	234.5	86.7	233.7	88.8	232.9	90.8	232.1	92.8
260	244.6	88.1	243.9	90.2	243.1	92.3	242.2	94.4	241.4	96.6
270	254.0	91.5	253.2	93.7	252.4	95.9	251.6	98.1	250.7	100.3
280	263.4	94.8	262.6	97.1	261.8	99.4	260.9	101.7	260.0	104.0
290	272.9	98.2	272.0	100.6	271.1	103.0	270.2	105.3	269.3	107.7
300	282.3	101.6	281.4	104.1	280.4	106.5	279.5	109.0	278.5	111.4

	41%		42%		43%		44%		45%	
	Angle 22°18		Angle 22°47		Angle 23°16		Angle 23°45		Angle 24°14	
40	37.0	15.2	36.9	15.5	36.7	15.8	36.6	16.1	36.5	16.4
50	46.3	19.0	46.1	19.4	45.9	19.8	45.8	20.1	45.6	20.5
60	55.5	22.8	55.3	23.2	55.1	23.7	54.9	24.2	54.7	24.6
70	64.8	26.6	64.5	27.1	64.3	27.7	64.1	28.2	63.8	28.7
80	74.0	30.4	73.8	31.0	73.5	31.6	73.2	32.2	73.0	32.8
90	83.3	34.2	83.0	34.9	82.7	35.6	82.4	36.2	82.1	36.9
100	92.5	37.9	92.2	38.7	91.9	39.5	91.5	40.3	91.2	41.0
110	101.8	41.7	101.4	42.6	101.1	43.5	100.7	44.3	100.3	45.1
120	111.0	45.5	110.6	46.5	110.2	47.4	109.8	48.3	109.4	49.3
130	120.3	49.3	119.9	50.3	119.4	51.4	119.0	52.4	118.5	53.4
140	129.5	53.1	129.1	54.2	128.6	55.3	128.1	56.4	127.7	57.5
150	138.8	56.9	138.3	58.1	137.8	59.3	137.3	60.4	136.8	61.6
160	148.0	60.7	147.5	62.0	147.0	63.2	146.4	64.4	145.9	65.7
170	157.3	64.5	156.7	65.8	156.2	67.2	155.6	68.5	155.0	69.8
180	166.5	68.3	166.0	69.7	165.4	71.1	164.8	72.5	164.1	73.9
190	175.8	72.1	175.2	73.6	174.5	75.1	173.9	76.5	173.3	78.0
200	185.0	75.9	184.4	77.4	183.7	79.0	183.1	80.5	182.4	82.1
210	194.3	79.7	193.6	81.3	192.9	83.0	192.2	84.6	191.5	86.2
220	203.5	83.5	202.8	85.2	202.1	86.9	201.4	88.6	200.6	90.3
230	212.8	87.3	212.1	89.1	211.3	90.9	210.5	92.6	209.7	94.4
240	222.1	91.1	221.3	92.9	220.5	94.8	219.7	96.7	218.9	98.5
250	231.3	94.9	230.5	96.8	229.7	98.8	228.8	100.7	228.0	102.6
260	240.6	98.7	239.7	100.7	238.9	102.7	238.0	104.7	237.1	106.7
270	249.8	102.5	248.9	104.6	248.0	106.7	247.1	108.7	246.2	110.8
280	259.1	106.2	258.2	108.4	257.2	110.6	256.3	112.8	255.3	114.9
290	268.3	110.0	267.4	112.3	266.4	114.6	265.4	116.8	264.4	119.0
300	277.6	113.8	276.6	116.2	275.6	118.5	274.6	120.8	273.6	123.1

	46%		47%		48%		49%		50%	
	Angle 24°42		Angle 25°10		Angle 25°38		Angle 26°06		Angle 26°34	
40	36.3	16.7	36.2	17.0	36.1	17.3	35.9	17.6	35.8	17.9
50	45.4	20.9	45.3	21.3	45.1	21.6	44.9	22.0	44.7	22.4
60	54.5	25.1	54.3	25.5	54.1	26.0	53.9	26.4	53.7	26.8
70	63.6	29.3	63.4	29.8	63.1	30.3	62.9	30.8	62.6	31.3
80	72.7	33.4	72.4	34.0	72.1	34.6	71.8	35.2	71.6	35.8
90	81.8	37.6	81.5	38.3	81.1	38.9	80.8	39.6	80.5	40.3
100	90.9	41.8	90.5	42.5	90.2	43.3	89.8	44.0	89.4	44.7
110	99.9	46.0	99.6	46.8	99.2	47.6	98.8	48.4	98.4	49.2
120	109.0	50.1	108.6	51.0	108.2	51.9	107.8	52.8	107.3	53.7
130	118.1	54.3	117.7	55.3	117.2	56.2	116.7	57.2	116.3	58.1
140	127.2	58.5	126.7	59.5	126.2	60.6	125.7	61.6	125.2	62.6
150	136.3	62.7	135.8	63.8	135.2	64.9	134.7	66.0	134.2	67.1
160	145.4	66.9	144.8	68.0	144.3	69.2	143.7	70.4	143.1	71.6
170	154.4	71.0	153.9	72.3	153.3	73.5	152.7	74.8	152.0	76.0
180	163.5	75.2	162.9	76.5	162.3	77.9	161.6	79.2	161.0	80.5
190	172.6	79.4	172.0	80.8	171.3	82.2	170.6	83.6	169.9	85.0
200	181.7	83.6	181.0	85.1	180.3	86.5	179.6	88.0	178.9	89.4
210	190.8	87.8	190.1	89.3	189.3	90.8	188.6	92.4	187.8	93.9
220	199.9	91.9	199.1	93.6	198.3	95.2	197.6	96.8	196.8	98.4
230	209.0	96.1	208.2	97.8	207.4	99.5	206.5	101.2	205.7	102.9
240	218.0	100.3	217.2	102.1	216.4	103.8	215.5	105.6	214.7	107.3
250	227.1	104.5	226.3	106.3	225.4	108.2	224.5	110.0	223.6	111.8
260	236.2	108.6	235.3	110.6	234.4	112.5	233.5	114.4	232.5	116.3
270	245.3	112.8	244.4	114.8	243.4	116.8	242.5	118.8	241.5	120.8
280	254.4	117.0	253.4	119.1	252.4	121.1	251.4	123.2	250.4	125.2
290	263.5	121.2	262.5	123.3	261.5	125.5	260.4	127.6	259.4	129.7
300	272.6	125.4	271.5	127.6	270.5	129.8	269.4	132.0	268.3	134.2

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	51%		52%		53%		54%		55%	
	Angle 27°01		Angle 27°28		Angle 27°55		Angle 28°22		Angle 28°49	
40	35.6	18.2	35.5	18.4	35.3	18.7	35.2	19.0	35.0	19.3
50	44.5	22.7	44.4	23.1	44.2	23.4	44.0	23.8	43.8	24.1
60	53.5	27.3	53.2	27.7	53.0	28.1	52.8	28.5	52.6	28.9
70	62.4	31.8	62.1	32.3	61.9	32.8	61.6	33.3	61.3	33.7
80	71.3	36.3	71.0	36.9	70.7	37.5	70.4	38.0	70.1	38.6
90	80.2	40.9	79.9	41.5	79.5	42.1	79.2	42.8	78.9	43.4
100	89.1	45.4	88.7	46.1	88.4	46.8	88.0	47.5	87.6	48.2
110	98.0	50.0	97.6	50.7	97.2	51.5	96.8	52.3	96.4	53.0
120	106.9	54.5	106.5	55.3	106.0	56.2	105.6	57.0	105.1	57.8
130	115.8	59.1	115.3	60.0	114.9	60.9	114.4	61.8	113.9	62.7
140	124.7	63.6	124.2	64.6	123.7	65.5	123.2	66.5	122.7	67.5
150	133.6	68.1	133.1	69.2	132.5	70.2	132.0	71.3	131.4	72.3
160	142.5	72.7	142.0	73.8	141.4	74.9	140.8	76.0	140.2	77.1
170	151.4	77.2	150.8	78.4	150.2	79.6	149.6	80.8	148.9	81.9
180	160.4	81.8	159.7	83.0	159.1	84.3	158.4	85.5	157.7	86.8
190	169.3	86.3	168.6	87.6	167.9	89.0	167.2	90.3	166.5	91.6
200	178.2	90.9	177.5	92.2	176.7	93.6	176.0	95.0	175.2	96.4
210	187.1	95.4	186.3	96.9	185.6	98.3	184.8	99.8	184.0	101.2
220	196.0	99.9	195.2	101.5	194.4	103.0	193.6	104.5	192.8	106.0
230	204.9	104.5	204.1	106.1	203.2	107.7	202.4	109.3	201.5	110.9
240	213.8	109.0	212.9	110.7	212.1	112.4	211.2	114.0	210.3	115.7
250	222.7	113.6	221.8	115.3	220.9	117.0	220.0	118.8	219.0	120.5
260	231.6	118.1	230.7	119.9	229.7	121.7	228.8	123.5	227.8	125.3
270	240.5	122.6	239.6	124.5	238.6	126.4	237.6	128.3	236.6	130.1
280	249.4	127.2	248.4	129.1	247.4	131.1	246.4	133.0	245.3	135.0
290	258.4	131.7	257.3	133.8	256.3	135.8	255.2	137.8	254.1	139.8
300	267.3	136.3	266.2	138.4	265.1	140.5	264.0	142.5	262.9	144.6

	56%		57%		58%		59%		60%	
	Angle 29°15		Angle 29°41		Angle 30°07		Angle 30°32		Angle 30°58	
40	34.9	19.5	34.8	19.8	34.6	20.1	34.5	20.3	34.3	20.6
50	43.6	24.4	43.4	24.8	43.3	25.1	43.1	25.4	42.9	25.7
60	52.4	29.3	52.1	29.7	51.9	30.1	51.7	30.5	51.4	30.9
70	61.1	34.2	60.8	34.7	60.6	35.1	60.3	35.6	60.0	36.0
80	69.8	39.1	69.5	39.6	69.2	40.1	68.9	40.6	68.6	41.2
90	78.5	44.0	78.2	44.6	77.9	45.2	77.5	45.7	77.2	46.3
100	87.3	48.9	86.9	49.5	86.5	50.2	86.1	50.8	85.7	51.5
110	96.0	53.7	95.6	54.5	95.2	55.2	94.7	55.9	94.3	56.6
120	104.7	58.6	104.3	59.4	103.8	60.2	103.4	61.0	102.9	61.7
130	113.4	63.5	112.9	64.4	112.5	65.2	112.0	66.0	111.5	66.9
140	122.2	68.4	121.6	69.3	121.1	70.2	120.6	71.1	120.0	72.0
150	130.9	73.3	130.3	74.3	129.8	75.3	129.2	76.2	128.6	77.2
160	139.6	78.2	139.0	79.2	138.4	80.3	137.8	81.3	137.2	82.3
170	148.3	83.1	147.7	84.2	147.1	85.3	146.4	86.4	145.8	87.5
180	157.1	88.0	156.4	89.1	155.7	90.3	155.0	91.4	154.3	92.6
190	165.8	92.8	165.1	94.1	164.4	95.3	163.7	96.5	162.9	97.8
200	174.5	97.7	173.8	99.0	173.0	100.4	172.3	101.6	171.5	102.9
210	183.2	102.6	182.4	104.0	181.7	105.4	180.9	106.7	180.1	108.1
220	192.0	107.5	191.1	108.9	190.3	110.4	189.5	111.8	188.6	113.2
230	200.7	112.4	199.8	113.9	199.0	115.4	198.1	116.8	197.2	118.3
240	209.4	117.3	208.5	118.9	207.6	120.4	206.7	121.9	205.8	123.5
250	218.1	122.2	217.2	123.8	216.3	125.4	215.3	127.0	214.4	128.6
260	226.9	127.0	225.9	128.8	224.9	130.5	223.9	132.1	222.9	133.8
270	235.6	131.9	234.6	133.7	233.6	135.5	232.6	137.2	231.5	138.9
280	244.3	136.8	243.3	138.7	242.2	140.5	241.2	142.3	240.1	144.1
290	253.0	141.7	251.9	143.6	250.9	145.5	249.8	147.3	248.7	149.2
300	261.8	146.6	260.6	148.6	259.5	150.5	258.4	152.4	257.2	154.4

	61%		62%		63%		64%		65%	
	Angle 31°23		Angle 31°48		Angle 32°13		Angle 32°37		Angle 33°01	
40	34.1	20.8	34.0	21.1	33.8	21.3	33.7	21.6	33.5	21.8
50	42.7	26.0	42.5	26.3	42.3	26.7	42.1	27.0	41.9	27.2
60	51.2	31.2	51.0	31.6	50.8	32.0	50.5	32.3	50.3	32.7
70	59.8	36.5	59.5	36.9	59.2	37.3	59.0	37.7	58.7	38.1
80	68.3	41.7	68.0	42.2	67.7	42.6	67.4	43.1	67.1	43.6
90	76.8	46.9	76.5	47.4	76.1	48.0	75.8	48.5	75.5	49.0
100	85.4	52.1	85.0	52.7	84.6	53.3	84.2	53.9	83.9	54.5
110	93.9	57.3	93.5	58.0	93.1	58.6	92.7	59.3	92.2	59.9
120	102.4	62.5	102.0	63.2	101.5	64.0	101.1	64.7	100.6	65.4
130	111.0	67.7	110.5	68.5	110.0	69.3	109.5	70.1	109.0	70.8
140	119.5	72.9	119.0	73.8	118.4	74.6	117.9	75.5	117.4	76.3
150	128.1	78.1	127.5	79.0	126.9	80.0	126.3	80.9	125.8	81.7
160	136.6	83.3	136.0	84.3	135.4	85.3	134.8	86.2	134.2	87.2
170	145.1	88.5	144.5	89.6	143.8	90.6	143.2	91.6	142.5	92.6
180	153.7	93.7	153.0	94.9	152.3	96.0	151.6	97.0	150.9	98.1
190	162.2	98.9	161.5	100.1	160.7	101.3	160.0	102.4	159.3	103.5
200	170.7	104.2	170.0	105.4	169.2	106.6	168.5	107.8	167.7	109.0
210	179.3	109.4	178.5	110.7	177.7	112.0	176.9	113.2	176.1	114.4
220	187.8	114.6	187.0	115.9	186.1	117.3	185.3	118.6	184.5	119.9
230	196.4	119.8	195.5	121.2	194.6	122.6	193.7	124.0	192.9	125.3
240	204.9	125.0	204.0	126.5	203.0	127.9	202.2	129.4	201.2	130.8
250	213.4	130.2	212.5	131.7	211.5	133.3	210.6	134.8	209.6	136.2
260	222.0	135.4	221.0	137.0	220.0	138.6	219.0	140.1	218.0	141.7
270	230.5	140.6	229.5	142.3	228.4	143.9	227.4	145.5	226.4	147.1
280	239.0	145.8	238.0	147.5	236.9	149.3	235.8	150.9	234.8	152.6
290	247.6	151.0	246.5	152.8	245.4	154.6	244.3	156.3	243.2	158.0
300	256.1	156.2	255.0	158.1	253.8	159.9	252.7	161.7	251.6	163.5

Compiled by Lester Calder

	66%		67%		68%		69%		70%	
	Angle 33°25		Angle 33°49		Angle 34°13		Angle 34°36		Angle 35°00	
40	33.4	22.0	33.2	22.3	33.1	22.5	32.9	22.7	32.8	22.9
50	41.7	27.5	41.5	27.8	41.3	28.1	41.2	28.4	41.0	28.7
60	50.1	33.0	49.8	33.4	49.6	33.7	49.4	34.1	49.1	34.4
70	58.4	38.6	58.2	39.0	57.9	39.4	57.6	39.7	57.3	40.2
80	66.8	44.1	66.5	44.5	66.2	45.0	65.9	45.4	65.5	45.9
90	75.1	49.6	74.8	50.1	74.4	50.6	74.1	51.1	73.7	51.6
100	83.5	55.1	83.1	55.7	82.7	56.2	82.3	56.8	81.9	57.4
110	91.8	60.6	91.4	61.2	91.0	61.9	90.5	62.5	90.1	63.1
120	100.2	66.1	99.7	66.8	99.2	67.5	98.8	68.1	98.3	68.8
130	108.5	71.6	108.0	72.4	107.5	73.1	107.0	73.8	106.5	74.6
140	116.9	77.1	116.3	77.9	115.8	78.7	115.2	79.5	114.7	80.3
150	125.2	82.6	124.6	83.5	124.0	84.3	123.5	85.2	122.9	86.0
160	133.6	88.1	132.9	89.0	132.3	90.0	131.7	90.9	131.1	91.8
170	141.9	93.6	141.2	94.6	140.6	95.6	139.9	96.5	139.3	97.5
180	150.2	99.1	149.5	100.2	148.8	101.2	148.2	102.2	147.4	103.2
190	158.6	104.6	157.9	105.7	157.1	106.8	156.4	107.9	155.6	109.0
200	166.9	110.1	166.2	111.3	165.4	112.5	164.6	113.6	163.8	114.7
210	175.3	115.7	174.5	116.9	173.7	118.1	172.9	119.2	172.0	120.5
220	183.6	121.2	182.8	122.4	181.9	123.7	181.1	124.9	180.2	126.2
230	192.0	126.7	191.1	128.0	190.2	129.3	189.3	130.6	188.4	131.9
240	200.3	132.2	199.4	133.6	198.5	135.0	197.6	136.3	196.6	137.7
250	208.7	137.7	207.7	139.1	206.7	140.6	205.8	142.0	204.8	143.4
260	217.0	143.2	216.0	144.7	215.0	146.2	214.0	147.6	213.0	149.1
270	225.4	148.7	224.3	150.3	223.3	151.8	222.2	153.3	221.2	154.9
280	233.7	154.2	232.6	155.8	231.5	157.4	230.5	159.0	229.4	160.6
290	242.1	159.7	240.9	161.4	239.8	163.1	238.7	164.7	237.6	166.3
300	250.4	165.2	249.2	167.0	248.1	168.7	246.9	170.4	245.7	172.1

	71%		72%		73%		74%		75%	
	Angle 35°22		Angle 35°45		Angle 36°08		Angle 36°30		Angle 36°52	
40	32.6	23.2	32.5	23.4	32.3	23.6	32.2	23.8	32.0	24.0
50	40.8	28.9	40.6	29.2	40.4	29.5	40.2	29.7	40.0	30.0
60	48.9	34.7	48.7	35.1	48.5	35.4	48.2	35.7	48.0	36.0
70	57.1	40.5	56.8	40.9	56.5	41.3	56.3	41.6	56.0	42.0
80	65.2	46.3	64.9	46.7	64.6	47.2	64.3	47.6	64.0	48.0
90	73.4	52.1	73.0	52.6	72.7	53.1	72.3	53.5	72.0	54.0
100	81.5	57.9	81.2	58.4	80.8	59.0	80.4	59.5	80.0	60.0
110	89.7	63.7	89.3	64.3	88.8	64.9	88.4	65.4	88.0	66.0
120	97.9	69.5	97.4	70.1	96.9	70.8	96.5	71.4	96.0	72.0
130	106.0	75.2	105.5	76.0	105.0	76.7	104.5	77.3	104.0	78.0
140	114.2	81.0	113.6	81.8	113.1	82.6	112.5	83.3	112.0	84.0
150	122.3	86.8	121.7	87.6	121.1	88.5	120.6	89.2	120.0	90.0
160	130.5	92.6	129.9	93.5	129.2	94.3	128.6	95.2	128.0	96.0
170	138.6	98.4	138.0	99.3	137.3	100.2	136.7	101.1	136.0	102.0
180	146.8	104.2	146.1	105.2	145.4	106.1	144.7	107.1	144.0	108.0
190	154.9	110.0	154.2	111.0	153.5	112.0	152.7	113.0	152.0	114.0
200	163.1	115.8	162.3	116.9	161.5	117.9	160.8	119.0	160.0	120.0
210	171.2	121.6	170.4	122.7	169.6	123.8	168.8	124.9	168.0	126.0
220	179.4	127.3	178.5	128.5	177.7	129.7	176.8	130.9	176.0	132.0
230	187.6	133.1	186.7	134.4	185.8	135.6	184.9	136.8	184.0	138.0
240	195.7	138.9	194.8	140.2	193.8	141.5	192.9	142.8	192.0	144.0
250	203.9	144.7	202.9	146.1	201.9	147.4	201.0	148.7	200.0	150.0
260	212.0	150.5	211.0	151.9	210.0	153.3	209.0	154.7	208.0	156.0
270	220.2	156.3	219.1	157.7	218.1	159.2	217.0	160.6	216.0	162.0
280	228.3	162.1	227.2	163.6	226.1	165.1	225.1	166.5	224.0	168.0
290	236.5	167.9	235.4	169.4	234.2	171.0	233.1	172.5	232.0	174.0
300	244.6	173.6	243.5	175.3	242.3	176.9	241.2	178.4	240.0	180.0

	76%		77%		78%		79%		80%	
	Angle 37°14		Angle 37°36		Angle 37°57		Angle 38°19		Angle 38°40	
40	31.8	24.2	31.7	24.4	31.5	24.6	31.4	24.8	31.2	25.0
50	39.8	30.3	39.6	30.5	39.4	30.7	39.2	31.0	39.0	31.2
60	47.8	36.3	47.5	36.6	47.3	36.9	47.1	37.2	46.8	37.5
70	55.7	42.4	55.5	42.7	55.2	43.0	54.9	43.4	54.7	43.7
80	63.7	48.4	63.4	48.8	63.1	49.2	62.8	49.6	62.5	50.0
90	71.7	54.5	71.3	54.9	71.0	55.3	70.6	55.8	70.3	56.2
100	79.6	60.5	79.2	61.0	78.9	61.5	78.5	62.0	78.1	62.5
110	87.6	66.6	87.2	67.1	86.7	67.6	86.3	68.2	85.9	68.7
120	95.5	72.6	95.1	73.2	94.6	73.8	94.2	74.4	93.7	75.0
130	103.5	78.7	103.0	79.3	102.5	79.9	102.0	80.6	101.5	81.2
140	111.5	84.7	110.9	85.4	110.4	86.1	109.8	86.8	109.3	87.5
150	119.4	90.8	118.8	91.5	118.3	92.2	117.7	93.0	117.1	93.7
160	127.4	96.8	126.8	97.6	126.2	98.4	125.5	99.2	124.9	100.0
170	135.4	102.9	134.7	103.7	134.1	104.5	133.4	105.4	132.7	106.2
180	143.3	108.9	142.6	109.8	141.9	110.7	141.2	111.6	140.5	112.5
190	151.3	115.0	150.5	115.9	149.8	116.8	149.1	117.8	148.4	118.7
200	159.2	121.0	158.5	122.0	157.7	123.0	156.9	124.0	156.2	125.0
210	167.2	127.1	166.4	128.1	165.6	129.1	164.8	130.2	164.0	131.2
220	175.2	133.1	174.3	134.2	173.5	135.3	172.6	136.4	171.8	137.5
230	183.1	139.2	182.2	140.3	181.4	141.4	180.5	142.6	179.6	143.7
240	191.1	145.2	190.1	146.4	189.3	147.6	188.3	148.8	187.4	149.9
250	199.0	151.3	198.1	152.5	197.1	153.7	196.2	155.0	195.2	156.2
260	207.0	157.3	206.0	158.6	205.0	159.9	204.0	161.2	203.0	162.4
270	215.0	163.4	213.9	164.7	212.9	166.0	211.8	167.4	210.8	168.7
280	222.9	169.4	221.8	170.8	220.8	172.2	219.7	173.6	218.6	174.9
290	230.9	175.5	229.8	176.9	228.7	178.3	227.5	179.8	226.4	181.2
300	238.9	181.5	237.7	183.0	236.6	184.5	235.4	186.0	234.2	187.5

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	Angle	Cos	Sin		Angle	Cos	Sin
81%	39°00	.777	.629	116%	49°14	.653	.757
82%	39°21	.773	.634	117%	49°29	.650	.760
83%	39°42	.769	.639	118%	49°43	.647	.763
84%	40°02	.766	.643	119%	49°58	.643	.766
85%	40°22	.762	.648	120%	50°12	.640	.768
86%	40°42	.758	.652	121%	50°26	.637	.771
87%	41°01	.755	.656	122%	50°40	.634	.773
88%	41°21	.751	.661	123%	50°53	.631	.776
89%	41°40	.747	.665	124%	51°07	.628	.778
90%	41°59	.743	.669	125%	51°20	.625	.781
91%	42°18	.740	.673	126%	51°34	.622	.783
92%	42°37	.736	.677	127%	51°47	.619	.786
93%	42°55	.732	.681	128%	52°00	.616	.788
94%	43°14	.729	.685	129%	52°13	.613	.790
95%	43°32	.725	.689	130%	52°26	.610	.793
96%	43°50	.721	.693	131%	52°39	.607	.795
97%	44°08	.718	.696	132%	52°51	.604	.797
98%	44°25	.714	.700	133%	53°04	.601	.799
99%	44°43	.711	.704	134%	53°16	.598	.801
100%	45°00	.707	.707	135%	53°28	.595	.804
101%	45°17	.704	.711	136%	53°40	.592	.806
102%	45°34	.700	.714	137%	53°52	.590	.808
103%	45°51	.697	.718	138%	54°04	.587	.810
104%	46°07	.693	.721	139%	54°16	.584	.812
105%	46°24	.690	.724	140%	54°28	.581	.814
106%	46°40	.686	.727	141%	54°39	.579	.816
107%	46°56	.683	.731	142%	54°51	.576	.818
108%	47°12	.679	.734	143%	55°02	.573	.819
109%	47°28	.676	.737	144%	55°13	.570	.821
110%	47°44	.673	.740	145%	55°24	.568	.823
111%	47°59	.669	.743	146%	55°35	.565	.825
112%	48°14	.666	.746	147%	55°46	.563	.827
113%	48°30	.663	.749	148%	55°57	.560	.829
114%	48°45	.659	.752	149%	56°08	.557	.830
115%	48°59	.656	.755	150%	56°19	.555	.832

Table 6. Natural trigonometric functions.

Values of the trigonometric functions of angles **for each minute** from 0 - 360°.

For degrees indicated at the top of the page use the **column** headings at the top. For degrees indicated at the **bottom** use the column indications at the bottom.

With degrees at the left of each block (top or bottom), **use the minute column at the left and with degrees at the right of each block use the minute column at the right.**

NATURAL FUNCTIONS (Continued)

0° (180°) — (359°) 179°

′	Sin	Tan	Cot	Cos	′
0	.00000	.00000		1.0000	60
1	.00029	.00029	3437.7	1.0000	59
2	.00058	.00058	1718.9	1.0000	58
3	.00087	.00087	1145.9	1.0000	57
4	.00116	.00116	859.44	1.0000	56
5	.00145	.00145	687.55	1.0000	55
6	.00175	.00175	572.96	1.0000	54
7	.00204	.00204	491.11	1.0000	53
8	.00233	.00233	429.72	1.0000	52
9	.00262	.00262	381.97	1.0000	51
10	.00291	.00291	343.77	1.0000	50
11	.00320	.00320	312.52	.99999	49
12	.00349	.00349	286.48	.99999	48
13	.00378	.00378	264.44	.99999	47
14	.00407	.00407	245.55	.99999	46
15	.00436	.00436	229.18	.99999	45
16	.00465	.00465	214.86	.99999	44
17	.00495	.00495	202.22	.99999	43
18	.00524	.00524	190.98	.99999	42
19	.00553	.00553	180.93	.99998	41
20	.00582	.00582	171.89	.99998	40
21	.00611	.00611	163.70	.99998	39
22	.00640	.00640	156.26	.99998	38
23	.00669	.00669	149.47	.99998	37
24	.00698	.00698	143.24	.99998	36
25	.00727	.00727	137.51	.99997	35
26	.00756	.00756	132.22	.99997	34
27	.00785	.00785	127.32	.99997	33
28	.00814	.00815	122.77	.99997	32
29	.00844	.00844	118.54	.99996	31
30	.00873	.00873	114.59	.99996	30
31	.00902	.00902	110.89	.99996	29
32	.00931	.00931	107.43	.99996	28
33	.00960	.00960	104.17	.99995	27
34	.00989	.00989	101.11	.99995	26
35	.01018	.01018	98.218	.99995	25
36	.01047	.01047	95.489	.99995	24
37	.01076	.01076	92.908	.99994	23
38	.01105	.01105	90.463	.99994	22
39	.01134	.01135	88.144	.99994	21
40	.01164	.01164	85.940	.99993	20
41	.01193	.01193	83.844	.99993	19
42	.01222	.01222	81.847	.99993	18
43	.01251	.01251	79.943	.99992	17
44	.01280	.01280	78.126	.99992	16
45	.01309	.01309	76.390	.99991	15
46	.01338	.01338	74.729	.99991	14
47	.01367	.01367	73.139	.99991	13
48	.01396	.01396	71.615	.99990	12
49	.01425	.01425	70.153	.99990	11
50	.01454	.01455	68.750	.99989	10
51	.01483	.01484	67.402	.99989	9
52	.01513	.01513	66.105	.99989	8
53	.01542	.01542	64.858	.99988	7
54	.01571	.01571	63.657	.99988	6
55	.01600	.01600	62.499	.99987	5
56	.01629	.01629	61.383	.99987	4
57	.01658	.01658	60.306	.99986	3
58	.01687	.01687	59.266	.99986	2
59	.01716	.01716	58.261	.99985	1
60	.01745	.01746	57.290	.99985	0
′	Cos	Cot	Tan	Sin	′

90° (270°) — (269°) 89°

1° (181°) — (358°) 178°

′	Sin	Tan	Cot	Cos	′
0	.01745	.01746	57.290	.99985	60
1	.01774	.01775	56.351	.99984	59
2	.01803	.01804	55.442	.99984	58
3	.01832	.01833	54.561	.99983	57
4	.01862	.01862	53.709	.99983	56
5	.01891	.01891	52.882	.99982	55
6	.01920	.01920	52.081	.99982	54
7	.01949	.01949	51.303	.99981	53
8	.01978	.01978	50.549	.99980	52
9	.02007	.02007	49.816	.99980	51
10	.02036	.02036	49.104	.99979	50
11	.02065	.02066	48.412	.99979	49
12	.02094	.02095	47.740	.99978	48
13	.02123	.02124	47.085	.99977	47
14	.02152	.02153	46.449	.99977	46
15	.02181	.02182	45.829	.99976	45
16	.02211	.02211	45.226	.99976	44
17	.02240	.02240	44.639	.99975	43
18	.02269	.02269	44.066	.99974	42
19	.02298	.02298	43.508	.99974	41
20	.02327	.02328	42.964	.99973	40
21	.02356	.02357	42.433	.99972	39
22	.02385	.02386	41.916	.99972	38
23	.02414	.02415	41.411	.99971	37
24	.02443	.02444	40.917	.99970	36
25	.02472	.02473	40.436	.99969	35
26	.02501	.02502	39.965	.99969	34
27	.02530	.02531	39.506	.99968	33
28	.02560	.02560	39.057	.99967	32
29	.02589	.02589	38.618	.99966	31
30	.02618	.02619	38.188	.99966	30
31	.02647	.02648	37.769	.99965	29
32	.02676	.02677	37.358	.99964	28
33	.02705	.02706	36.956	.99963	27
34	.02734	.02735	36.563	.99963	26
35	.02763	.02764	36.178	.99962	25
36	.02792	.02793	35.801	.99961	24
37	.02821	.02822	35.431	.99960	23
38	.02850	.02851	35.070	.99959	22
39	.02879	.02881	34.715	.99959	21
40	.02908	.02910	34.368	.99958	20
41	.02938	.02939	34.027	.99957	19
42	.02967	.02968	33.694	.99956	18
43	.02996	.02997	33.366	.99955	17
44	.03025	.03026	33.045	.99954	16
45	.03054	.03055	32.730	.99953	15
46	.03083	.03084	32.421	.99952	14
47	.03112	.03114	32.118	.99952	13
48	.03141	.03143	31.821	.99951	12
49	.03170	.03172	31.528	.99950	11
50	.03199	.03201	31.242	.99949	10
51	.03228	.03230	30.960	.99948	9
52	.03257	.03259	30.683	.99947	8
53	.03286	.03288	30.412	.99946	7
54	.03316	.03317	30.145	.99945	6
55	.03345	.03346	29.882	.99944	5
56	.03374	.03376	29.624	.99943	4
57	.03403	.03405	29.371	.99942	3
58	.03432	.03434	29.122	.99941	2
59	.03461	.03463	28.877	.99940	1
60	.03490	.03492	28.636	.99939	0
′	Cos	Cot	Tan	Sin	′

91° (271°) — (268°) 88°

NATURAL FUNCTIONS (Continued)

2° (182°) (357°) 177°

′	Sin	Tan	Cot	Cos	′
0	.03490	.03492	28.636	.99939	60
1	.03519	.03521	28.399	.99938	59
2	.03548	.03550	28.166	.99937	58
3	.03577	.03579	27.937	.99936	57
4	.03606	.03609	27.712	.99935	56
5	.03635	.03638	27.490	.99934	55
6	.03664	.03667	27.271	.99933	54
7	.03693	.03696	27.057	.99932	53
8	.03723	.03725	26.845	.99931	52
9	.03752	.03754	26.637	.99930	51
10	.03781	.03783	26.432	.99929	50
11	.03810	.03812	26.230	.99927	49
12	.03839	.03842	26.031	.99926	48
13	.03868	.03871	25.835	.99925	47
14	.03897	.03900	25.642	.99924	46
15	.03926	.03929	25.452	.99923	45
16	.03955	.03958	25.264	.99922	44
17	.03984	.03987	25.080	.99921	43
18	.04013	.04016	24.898	.99919	42
19	.04042	.04046	24.719	.99918	41
20	.04071	.04075	24.542	.99917	40
21	.04100	.04104	24.368	.99916	39
22	.04129	.04133	24.196	.99915	38
23	.04159	.04162	24.026	.99913	37
24	.04188	.04191	23.859	.99912	36
25	.04217	.04220	23.695	.99911	35
26	.04246	.04250	23.532	.99910	34
27	.04275	.04279	23.372	.99909	33
28	.04304	.04308	23.214	.99907	32
29	.04333	.04337	23.058	.99906	31
30	.04362	.04366	22.904	.99905	30
31	.04391	.04395	22.752	.99904	29
32	.04420	.04424	22.602	.99902	28
33	.04449	.04454	22.454	.99901	27
34	.04478	.04483	22.308	.99900	26
35	.04507	.04512	22.164	.99898	25
36	.04536	.04541	22.022	.99897	24
37	.04565	.04570	21.881	.99896	23
38	.04594	.04599	21.743	.99894	22
39	.04623	.04628	21.606	.99893	21
40	.04653	.04658	21.470	.99892	20
41	.04682	.04687	21.337	.99890	19
42	.04711	.04716	21.205	.99889	18
43	.04740	.04745	21.075	.99888	17
44	.04769	.04774	20.946	.99886	16
45	.04798	.04803	20.819	.99885	15
46	.04827	.04833	20.693	.99883	14
47	.04856	.04862	20.569	.99882	13
48	.04885	.04891	20.446	.99881	12
49	.04914	.04920	20.325	.99879	11
50	.04943	.04949	20.206	.99878	10
51	.04972	.04978	20.087	.99876	9
52	.05001	.05007	19.970	.99875	8
53	.05030	.05037	19.855	.99873	7
54	.05059	.05066	19.740	.99872	6
55	.05088	.05095	19.627	.99870	5
56	.05117	.05124	19.516	.99869	4
57	.05146	.05153	19.405	.99867	3
58	.05175	.05182	19.296	.99866	2
59	.05205	.05212	19.188	.99864	1
60	.05234	.05241	19.081	.99863	0
′	Cos	Cot	Tan	Sin	′

92° (272°) (267°) 87°

3° (183°) (356°) 176°

′	Sin	Tan	Cot	Cos	′
0	.05234	.05241	19.081	.99863	60
1	.05263	.05270	18.976	.99861	59
2	.05292	.05299	18.871	.99860	58
3	.05321	.05328	18.768	.99858	57
4	.05350	.05357	18.666	.99857	56
5	.05379	.05387	18.564	.99855	55
6	.05408	.05416	18.464	.99854	54
7	.05437	.05445	18.366	.99852	53
8	.05466	.05474	18.268	.99851	52
9	.05495	.05503	18.171	.99849	51
10	.05524	.05533	18.075	.99847	50
11	.05553	.05562	17.980	.99846	49
12	.05582	.05591	17.886	.99844	48
13	.05611	.05620	17.793	.99842	47
14	.05640	.05649	17.702	.99841	46
15	.05669	.05678	17.611	.99839	45
16	.05698	.05708	17.521	.99838	44
17	.05727	.05737	17.431	.99836	43
18	.05756	.05766	17.343	.99834	42
19	.05785	.05795	17.256	.99833	41
20	.05814	.05824	17.169	.99831	40
21	.05844	.05854	17.084	.99829	39
22	.05873	.05883	16.999	.99827	38
23	.05902	.05912	16.915	.99826	37
24	.05931	.05941	16.832	.99824	36
25	.05960	.05970	16.750	.99822	35
26	.05989	.05999	16.668	.99821	34
27	.06018	.06029	16.587	.99819	33
28	.06047	.06058	16.507	.99817	32
29	.06076	.06087	16.428	.99815	31
30	.06105	.06116	16.350	.99813	30
31	.06134	.06145	16.272	.99812	29
32	.06163	.06175	16.195	.99810	28
33	.06192	.06204	16.119	.99808	27
34	.06221	.06233	16.043	.99806	26
35	.06250	.06262	15.969	.99804	25
36	.06279	.06291	15.895	.99803	24
37	.06308	.06321	15.821	.99801	23
38	.06337	.06350	15.748	.99799	22
39	.06366	.06379	15.676	.99797	21
40	.06395	.06408	15.605	.99795	20
41	.06424	.06438	15.534	.99793	19
42	.06453	.06467	15.464	.99792	18
43	.06482	.06496	15.394	.99790	17
44	.06511	.06525	15.325	.99788	16
45	.06540	.06554	15.257	.99786	15
46	.06569	.06584	15.189	.99784	14
47	.06598	.06613	15.122	.99782	13
48	.06627	.06642	15.056	.99780	12
49	.06656	.06671	14.990	.99778	11
50	.06685	.06700	14.924	.99776	10
51	.06714	.06730	14.860	.99774	9
52	.06743	.06759	14.795	.99772	8
53	.06773	.06788	14.732	.99770	7
54	.06802	.06817	14.669	.99768	6
55	.06831	.06847	14.606	.99766	5
56	.06860	.06876	14.544	.99764	4
57	.06889	.06905	14.482	.99762	3
58	.06918	.06934	14.421	.99760	2
59	.06947	.06963	14.361	.99758	1
60	.06976	.06993	14.301	.99756	0
′	Cos	Cot	Tan	Sin	′

93° (273°) (266°) 86°

NATURAL FUNCTIONS (Continued)

4° (184°) — (355°) 175°

′	Sin	Tan	Cot	Cos	′
0	.06976	.06993	14.301	.99756	60
1	.07005	.07022	14.241	.99754	59
2	.07034	.07051	14.182	.99752	58
3	.07063	.07080	14.124	.99750	57
4	.07092	.07110	14.065	.99748	56
5	.07121	.07139	14.008	.99746	55
6	.07150	.07168	13.951	.99744	54
7	.07179	.07197	13.894	.99742	53
8	.07208	.07227	13.838	.99740	52
9	.07237	.07256	13.782	.99738	51
10	.07266	.07285	13.727	.99736	50
11	.07295	.07314	13.672	.99734	49
12	.07324	.07344	13.617	.99731	48
13	.07353	.07373	13.563	.99729	47
14	.07382	.07402	13.510	.99727	46
15	.07411	.07431	13.457	.99725	45
16	.07440	.07461	13.404	.99723	44
17	.07469	.07490	13.352	.99721	43
18	.07498	.07519	13.300	.99719	42
19	.07527	.07548	13.248	.99716	41
20	.07556	.07578	13.197	.99714	40
21	.07585	.07607	13.146	.99712	39
22	.07614	.07636	13.096	.99710	38
23	.07643	.07665	13.046	.99708	37
24	.07672	.07695	12.996	.99705	36
25	.07701	.07724	12.947	.99703	35
26	.07730	.07753	12.898	.99701	34
27	.07759	.07782	12.850	.99699	33
28	.07788	.07812	12.801	.99696	32
29	.07817	.07841	12.754	.99694	31
30	.07846	.07870	12.706	.99692	30
31	.07875	.07899	12.659	.99689	29
32	.07904	.07929	12.612	.99687	28
33	.07933	.07958	12.566	.99685	27
34	.07962	.07987	12.520	.99683	26
35	.07991	.08017	12.474	.99680	25
36	.08020	.08046	12.429	.99678	24
37	.08049	.08075	12.384	.99676	23
38	.08078	.08104	12.339	.99673	22
39	.08107	.08134	12.295	.99671	21
40	.08136	.08163	12.251	.99668	20
41	.08165	.08192	12.207	.99666	19
42	.08194	.08221	12.163	.99664	18
43	.08223	.08251	12.120	.99661	17
44	.08252	.08280	12.077	.99659	16
45	.08281	.08309	12.035	.99657	15
46	.08310	.08339	11.992	.99654	14
47	.08339	.08368	11.950	.99652	13
48	.08368	.08397	11.909	.99649	12
49	.08397	.08427	11.867	.99647	11
50	.08426	.08456	11.826	.99644	10
51	.08455	.08485	11.785	.99642	9
52	.08484	.08514	11.745	.99639	8
53	.08513	.08544	11.705	.99637	7
54	.08542	.08573	11.664	.99635	6
55	.08571	.08602	11.625	.99632	5
56	.08600	.08632	11.585	.99630	4
57	.08629	.08661	11.546	.99627	3
58	.08658	.08690	11.507	.99625	2
59	.08687	.08720	11.468	.99622	1
60	.08716	.08749	11.430	.99619	0
′	Cos	Cot	Tan	Sin	′

94° (274°) — (265°) 85°

5° (185°) — (354°) 174°

′	Sin	Tan	Cot	Cos	′
0	.08716	.08749	11.430	.99619	60
1	.08745	.08778	11.392	.99617	59
2	.08774	.08807	11.354	.99614	58
3	.08803	.08837	11.316	.99612	57
4	.08831	.08866	11.279	.99609	56
5	.08860	.08895	11.242	.99607	55
6	.08889	.08925	11.205	.99604	54
7	.08918	.08954	11.168	.99602	53
8	.08947	.08983	11.132	.99599	52
9	.08976	.09013	11.095	.99596	51
10	.09005	.09042	11.059	.99594	50
11	.09034	.09071	11.024	.99591	49
12	.09063	.09101	10.988	.99588	48
13	.09092	.09130	10.953	.99586	47
14	.09121	.09159	10.918	.99583	46
15	.09150	.09189	10.883	.99580	45
16	.09179	.09218	10.848	.99578	44
17	.09208	.09247	10.814	.99575	43
18	.09237	.09277	10.780	.99572	42
19	.09266	.09306	10.746	.99570	41
20	.09295	.09335	10.712	.99567	40
21	.09324	.09365	10.678	.99564	39
22	.09353	.09394	10.645	.99562	38
23	.09382	.09423	10.612	.99559	37
24	.09411	.09453	10.579	.99556	36
25	.09440	.09482	10.546	.99553	35
26	.09469	.09511	10.514	.99551	34
27	.09498	.09541	10.481	.99548	33
28	.09527	.09570	10.449	.99545	32
29	.09556	.09600	10.417	.99542	31
30	.09585	.09629	10.385	.99540	30
31	.09614	.09658	10.354	.99537	29
32	.09642	.09688	10.322	.99534	28
33	.09671	.09717	10.291	.99531	27
34	.09700	.09746	10.260	.99528	26
35	.09729	.09776	10.229	.99526	25
36	.09758	.09805	10.199	.99523	24
37	.09787	.09834	10.168	.99520	23
38	.09816	.09864	10.138	.99517	22
39	.09845	.09893	10.108	.99514	21
40	.09874	.09923	10.078	.99511	20
41	.09903	.09952	10.048	.99508	19
42	.09932	.09981	10.019	.99506	18
43	.09961	.10011	9.9893	.99503	17
44	.09990	.10040	9.9601	.99500	16
45	.10019	.10069	9.9310	.99497	15
46	.10048	.10099	9.9021	.99494	14
47	.10077	.10128	9.8734	.99491	13
48	.10106	.10158	9.8448	.99488	12
49	.10135	.10187	9.8164	.99485	11
50	.10164	.10216	9.7882	.99482	10
51	.10192	.10246	9.7601	.99479	9
52	.10221	.10275	9.7322	.99476	8
53	.10250	.10305	9.7044	.99473	7
54	.10279	.10334	9.6768	.99470	6
55	.10308	.10363	9.6493	.99467	5
56	.10337	.10393	9.6220	.99464	4
57	.10366	.10422	9.5949	.99461	3
58	.10395	.10452	9.5679	.99458	2
59	.10424	.10481	9.5411	.99455	1
60	.10453	.10510	9.5144	.99452	0
′	Cos	Cot	Tan	Sin	′

95° (275°) — (264°) 84°

NATURAL FUNCTIONS (Continued)

6° (186°) — (353°) 173°

′	Sin	Tan	Cot	Cos	′
0	.10453	.10510	9.5144	.99452	60
1	.10482	.10540	9.4878	.99449	59
2	.10511	.10569	9.4614	.99446	58
3	.10540	.10599	9.4352	.99443	57
4	.10569	.10628	9.4090	.99440	56
5	.10597	.10657	9.3831	.99437	55
6	.10626	.10687	9.3572	.99434	54
7	.10655	.10716	9.3315	.99431	53
8	.10684	.10746	9.3060	.99428	52
9	.10713	.10775	9.2806	.99424	51
10	.10742	.10805	9.2553	.99421	50
11	.10771	.10834	9.2302	.99418	49
12	.10800	.10863	9.2052	.99415	48
13	.10829	.10893	9.1803	.99412	47
14	.10858	.10922	9.1555	.99409	46
15	.10887	.10952	9.1309	.99406	45
16	.10916	.10981	9.1065	.99402	44
17	.10945	.11011	9.0821	.99399	43
18	.10973	.11040	9.0579	.99396	42
19	.11002	.11070	9.0338	.99393	41
20	.11031	.11099	9.0098	.99390	40
21	.11060	.11128	8.9860	.99386	39
22	.11089	.11158	8.9623	.99383	38
23	.11118	.11187	8.9387	.99380	37
24	.11147	.11217	8.9152	.99377	36
25	.11176	.11246	8.8919	.99374	35
26	.11205	.11276	8.8686	.99370	34
27	.11234	.11305	8.8455	.99367	33
28	.11263	.11335	8.8225	.99364	32
29	.11291	.11364	8.7996	.99360	31
30	.11320	.11394	8.7769	.99357	30
31	.11349	.11423	8.7542	.99354	29
32	.11378	.11452	8.7317	.99351	28
33	.11407	.11482	8.7093	.99347	27
34	.11436	.11511	8.6870	.99344	26
35	.11465	.11541	8.6648	.99341	25
36	.11494	.11570	8.6427	.99337	24
37	.11523	.11600	8.6208	.99334	23
38	.11552	.11629	8.5989	.99331	22
39	.11580	.11659	8.5772	.99327	21
40	.11609	.11688	8.5555	.99324	20
41	.11638	.11718	8.5340	.99320	19
42	.11667	.11747	8.5126	.99317	18
43	.11696	.11777	8.4913	.99314	17
44	.11725	.11806	8.4701	.99310	16
45	.11754	.11836	8.4490	.99307	15
46	.11783	.11865	8.4280	.99303	14
47	.11812	.11895	8.4071	.99300	13
48	.11840	.11924	8.3863	.99297	12
49	.11869	.11954	8.3656	.99293	11
50	.11898	.11983	8.3450	.99290	10
51	.11927	.12013	8.3245	.99286	9
52	.11956	.12042	8.3041	.99283	8
53	.11985	.12072	8.2838	.99279	7
54	.12014	.12101	8.2636	.99276	6
55	.12043	.12131	8.2434	.99272	5
56	.12071	.12160	8.2234	.99269	4
57	.12100	.12190	8.2035	.99265	3
58	.12129	.12219	8.1837	.99262	2
59	.12158	.12249	8.1640	.99258	1
60	.12187	.12278	8.1443	.99255	0
′	Cos	Cot	Tan	Sin	′

96° (276°) — (263°) 83°

7° (187°) — (352°) 172°

′	Sin	Tan	Cot	Cos	′
0	.12187	.12278	8.1443	.99255	60
1	.12216	.12308	8.1248	.99251	59
2	.12245	.12338	8.1054	.99248	58
3	.12274	.12367	8.0860	.99244	57
4	.12302	.12397	8.0667	.99240	56
5	.12331	.12426	8.0476	.99237	55
6	.12360	.12456	8.0285	.99233	54
7	.12389	.12485	8.0095	.99230	53
8	.12418	.12515	7.9906	.99226	52
9	.12447	.12544	7.9718	.99222	51
10	.12476	.12574	7.9530	.99219	50
11	.12504	.12603	7.9344	.99215	49
12	.12533	.12633	7.9158	.99211	48
13	.12562	.12662	7.8973	.99208	47
14	.12591	.12692	7.8789	.99204	46
15	.12620	.12722	7.8606	.99200	45
16	.12649	.12751	7.8424	.99197	44
17	.12678	.12781	7.8243	.99193	43
18	.12706	.12810	7.8062	.99189	42
19	.12735	.12840	7.7882	.99186	41
20	.12764	.12869	7.7704	.99182	40
21	.12793	.12899	7.7525	.99178	39
22	.12822	.12929	7.7348	.99175	38
23	.12851	.12958	7.7171	.99171	37
24	.12880	.12988	7.6996	.99167	36
25	.12908	.13017	7.6821	.99163	35
26	.12937	.13047	7.6647	.99160	34
27	.12966	.13076	7.6473	.99156	33
28	.12995	.13106	7.6301	.99152	32
29	.13024	.13136	7.6129	.99148	31
30	.13053	.13165	7.5958	.99144	30
31	.13081	.13195	7.5787	.99141	29
32	.13110	.13224	7.5618	.99137	28
33	.13139	.13254	7.5449	.99133	27
34	.13168	.13284	7.5281	.99129	26
35	.13197	.13313	7.5113	.99125	25
36	.13226	.13343	7.4947	.99122	24
37	.13254	.13372	7.4781	.99118	23
38	.13283	.13402	7.4615	.99114	22
39	.13312	.13432	7.4451	.99110	21
40	.13341	.13461	7.4287	.99106	20
41	.13370	.13491	7.4124	.99102	19
42	.13399	.13521	7.3962	.99098	18
43	.13427	.13550	7.3800	.99094	17
44	.13456	.13580	7.3639	.99091	16
45	.13485	.13609	7.3479	.99087	15
46	.13514	.13639	7.3319	.99083	14
47	.13543	.13669	7.3160	.99079	13
48	.13572	.13698	7.3002	.99075	12
49	.13600	.13728	7.2844	.99071	11
50	.13629	.13758	7.2687	.99067	10
51	.13658	.13787	7.2531	.99063	9
52	.13687	.13817	7.2375	.99059	8
53	.13716	.13846	7.2220	.99055	7
54	.13744	.13876	7.2066	.99051	6
55	.13773	.13906	7.1912	.99047	5
56	.13802	.13935	7.1759	.99043	4
57	.13831	.13965	7.1607	.99039	3
58	.13860	.13995	7.1455	.99035	2
59	.13889	.14024	7.1304	.99031	1
60	.13917	.14054	7.1154	.99027	0
′	Cos	Cot	Tan	Sin	′

97° (277°) — (262°) 82°

NATURAL FUNCTIONS (Continued)

8° (188°) (351°) **171°**

′	Sin	Tan	Cot	Cos	′
0	.13917	.14054	7.1154	.99027	**60**
1	.13946	.14084	7.1004	.99023	59
2	.13975	.14113	7.0855	.99019	58
3	.14004	.14143	7.0706	.99015	57
4	.14033	.14173	7.0558	.99011	56
5	.14061	.14202	7.0410	.99006	**55**
6	.14090	.14232	7.0264	.99002	54
7	.14119	.14262	7.0117	.98998	53
8	.14148	.14291	6.9972	.98994	52
9	.14177	.14321	6.9827	.98990	51
10	.14205	.14351	6.9682	.98986	**50**
11	.14234	.14381	6.9538	.98982	49
12	.14263	.14410	6.9395	.98978	48
13	.14292	.14440	6.9252	.98973	47
14	.14320	.14470	6.9110	.98969	46
15	.14349	.14499	6.8969	.98965	**45**
16	.14378	.14529	6.8828	.98961	44
17	.14407	.14559	6.8687	.98957	43
18	.14436	.14588	6.8548	.98953	42
19	.14464	.14618	6.8408	.98948	41
20	.14493	.14648	6.8269	.98944	**40**
21	.14522	.14678	6.8131	.98940	39
22	.14551	.14707	6.7994	.98936	38
23	.14580	.14737	6.7856	.98931	37
24	.14608	.14767	6.7720	.98927	36
25	.14637	.14796	6.7584	.98923	**35**
26	.14666	.14826	6.7448	.98919	34
27	.14695	.14856	6.7313	.98914	33
28	.14723	.14886	6.7179	.98910	32
29	.14752	.14915	6.7045	.98906	31
30	.14781	.14945	6.6912	.98902	**30**
31	.14810	.14975	6.6779	.98897	29
32	.14838	.15005	6.6646	.98893	28
33	.14867	.15034	6.6514	.98889	27
34	.14896	.15064	6.6383	.98884	26
35	.14925	.15094	6.6252	.98880	**25**
36	.14954	.15124	6.6122	.98876	24
37	.14982	.15153	6.5992	.98871	23
38	.15011	.15183	6.5863	.98867	22
39	.15040	.15213	6.5734	.98863	21
40	.15069	.15243	6.5606	.98858	**20**
41	.15097	.15272	6.5478	.98854	19
42	.15126	.15302	6.5350	.98849	18
43	.15155	.15332	6.5223	.98845	17
44	.15184	.15362	6.5097	.98841	16
45	.15212	.15391	6.4971	.98836	**15**
46	.15241	.15421	6.4846	.98832	14
47	.15270	.15451	6.4721	.98827	13
48	.15299	.15481	6.4596	.98823	12
49	.15327	.15511	6.4472	.98818	11
50	.15356	.15540	6.4348	.98814	**10**
51	.15385	.15570	6.4225	.98809	9
52	.15414	.15600	6.4103	.98805	8
53	.15442	.15630	6.3980	.98800	7
54	.15471	.15660	6.3859	.98796	6
55	.15500	.15689	6.3737	.98791	**5**
56	.15529	.15719	6.3617	.98787	4
57	.15557	.15749	6.3496	.98782	3
58	.15586	.15779	6.3376	.98778	2
59	.15615	.15809	6.3257	.98773	1
60	.15643	.15838	6.3138	.98769	**0**
′	Cos	Cot	Tan	Sin	′

98° (278°) (261°) **81°**

9° (189°) (350°) **170°**

′	Sin	Tan	Cot	Cos	′
0	.15643	.15838	6.3138	.98769	**60**
1	.15672	.15868	6.3019	.98764	59
2	.15701	.15898	6.2901	.98760	58
3	.15730	.15928	6.2783	.98755	57
4	.15758	.15958	6.2666	.98751	56
5	.15787	.15988	6.2549	.98746	**55**
6	.15816	.16017	6.2432	.98741	54
7	.15845	.16047	6.2316	.98737	53
8	.15873	.16077	6.2200	.98732	52
9	.15902	.16107	6.2085	.98728	51
10	.15931	.16137	6.1970	.98723	**50**
11	.15959	.16167	6.1856	.98718	49
12	.15988	.16196	6.1742	.98714	48
13	.16017	.16226	6.1628	.98709	47
14	.16046	.16256	6.1515	.98704	46
15	.16074	.16286	6.1402	.98700	**45**
16	.16103	.16316	6.1290	.98695	44
17	.16132	.16346	6.1178	.98690	43
18	.16160	.16376	6.1066	.98686	42
19	.16189	.16405	6.0955	.98681	41
20	.16218	.16435	6.0844	.98676	**40**
21	.16246	.16465	6.0734	.98671	39
22	.16275	.16495	6.0624	.98667	38
23	.16304	.16525	6.0514	.98662	37
24	.16333	.16555	6.0405	.98657	36
25	.16361	.16585	6.0296	.98652	**35**
26	.16390	.16615	6.0188	.98648	34
27	.16419	.16645	6.0080	.98643	33
28	.16447	.16674	5.9972	.98638	32
29	.16476	.16704	5.9865	.98633	31
30	.16505	.16734	5.9758	.98629	**30**
31	.16533	.16764	5.9651	.98624	29
32	.16562	.16794	5.9545	.98619	28
33	.16591	.16824	5.9439	.98614	27
34	.16620	.16854	5.9333	.98609	26
35	.16648	.16884	5.9228	.98604	**25**
36	.16677	.16914	5.9124	.98600	24
37	.16706	.16944	5.9019	.98595	23
38	.16734	.16974	5.8915	.98590	22
39	.16763	.17004	5.8811	.98585	21
40	.16792	.17033	5.8708	.98580	**20**
41	.16820	.17063	5.8605	.98575	19
42	.16849	.17093	5.8502	.98570	18
43	.16878	.17123	5.8400	.98565	17
44	.16906	.17153	5.8298	.98561	16
45	.16935	.17183	5.8197	.98556	**15**
46	.16964	.17213	5.8095	.98551	14
47	.16992	.17243	5.7994	.98546	13
48	.17021	.17273	5.7894	.98541	12
49	.17050	.17303	5.7794	.98536	11
50	.17078	.17333	5.7694	.98531	**10**
51	.17107	.17363	5.7594	.98526	9
52	.17136	.17393	5.7495	.98521	8
53	.17164	.17423	5.7396	.98516	7
54	.17193	.17453	5.7297	.98511	6
55	.17222	.17483	5.7199	.98506	**5**
56	.17250	.17513	5.7101	.98501	4
57	.17279	.17543	5.7004	.98496	3
58	.17308	.17573	5.6906	.98491	2
59	.17336	.17603	5.6809	.98486	1
60	.17365	.17633	5.6713	.98481	**0**
′	Cos	Cot	Tan	Sin	′

99° (279°) (260°) **80°**

NATURAL FUNCTIONS (Continued)

10° (190°) (349°) **169°**

′	Sin	Tan	Cot	Cos	′
0	.17365	.17633	5.6713	.98481	**60**
1	.17393	.17663	5.6617	.98476	**59**
2	.17422	.17693	5.6521	.98471	**58**
3	.17451	.17723	5.6425	.98466	**57**
4	.17479	.17753	5.6329	.98461	**56**
5	.17508	.17783	5.6234	.98455	**55**
6	.17537	.17813	5.6140	.98450	**54**
7	.17565	.17843	5.6045	.98445	**53**
8	.17594	.17873	5.5951	.98440	**52**
9	.17623	.17903	5.5857	.98435	**51**
10	.17651	.17933	5.5764	.98430	**50**
11	.17680	.17963	5.5671	.98425	**49**
12	.17708	.17993	5.5578	.98420	**48**
13	.17737	.18023	5.5485	.98414	**47**
14	.17766	.18053	5.5393	.98409	**46**
15	.17794	.18083	5.5301	.98404	**45**
16	.17823	.18113	5.5209	.98399	**44**
17	.17852	.18143	5.5118	.98394	**43**
18	.17880	.18173	5.5026	.98389	**42**
19	.17909	.18203	5.4936	.98383	**41**
20	.17937	.18233	5.4845	.98378	**40**
21	.17966	.18263	5.4755	.98373	**39**
22	.17995	.18293	5.4665	.98368	**38**
23	.18023	.18323	5.4575	.98362	**37**
24	.18052	.18353	5.4486	.98357	**36**
25	.18081	.18384	5.4397	.98352	**35**
26	.18109	.18414	5.4308	.98347	**34**
27	.18138	.18444	5.4219	.98341	**33**
28	.18166	.18474	5.4131	.98336	**32**
29	.18195	.18504	5.4043	.98331	**31**
30	.18224	.18534	5.3955	.98325	**30**
31	.18252	.18564	5.3868	.98320	**29**
32	.18281	.18594	5.3781	.98315	**28**
33	.18309	.18624	5.3694	.98310	**27**
34	.18338	.18654	5.3607	.98304	**26**
35	.18367	.18684	5.3521	.98299	**25**
36	.18395	.18714	5.3435	.98294	**24**
37	.18424	.18745	5.3349	.98288	**23**
38	.18452	.18775	5.3263	.98283	**22**
39	.18481	.18805	5.3178	.98277	**21**
40	.18509	.18835	5.3093	.98272	**20**
41	.18538	.18865	5.3008	.98267	**19**
42	.18567	.18895	5.2924	.98261	**18**
43	.18595	.18925	5.2839	.98256	**17**
44	.18624	.18955	5.2755	.98250	**16**
45	.18652	.18986	5.2672	.98245	**15**
46	.18681	.19016	5.2588	.98240	**14**
47	.18710	.19046	5.2505	.98234	**13**
48	.18738	.19076	5.2422	.98229	**12**
49	.18767	.19106	5.2339	.98223	**11**
50	.18795	.19136	5.2257	.98218	**10**
51	.18824	.19166	5.2174	.98212	**9**
52	.18852	.19197	5.2092	.98207	**8**
53	.18881	.19227	5.2011	.98201	**7**
54	.18910	.19257	5.1929	.98196	**6**
55	.18938	.19287	5.1848	.98190	**5**
56	.18967	.19317	5.1767	.98185	**4**
57	.18995	.19347	5.1686	.98179	**3**
58	.19024	.19378	5.1606	.98174	**2**
59	.19052	.19408	5.1526	.98168	**1**
60	.19081	.19438	5.1446	.98163	**0**
′	Cos	Cot	Tan	Sin	′

100°(280°) (259°)**79°**

11° (191°) (348°) **168°**

′	Sin	Tan	Cot	Cos	′
0	.19081	.19438	5.1446	.98163	**60**
1	.19109	.19468	5.1366	.98157	**59**
2	.19138	.19498	5.1286	.98152	**58**
3	.19167	.19529	5.1207	.98146	**57**
4	.19195	.19559	5.1128	.98140	**56**
5	.19224	.19589	5.1049	.98135	**55**
6	.19252	.19619	5.0970	.98129	**54**
7	.19281	.19649	5.0892	.98124	**53**
8	.19309	.19680	5.0814	.98118	**52**
9	.19338	.19710	5.0736	.98112	**51**
10	.19366	.19740	5.0658	.98107	**50**
11	.19395	.19770	5.0581	.98101	**49**
12	.19423	.19801	5.0504	.98096	**48**
13	.19452	.19831	5.0427	.98090	**47**
14	.19481	.19861	5.0350	.98084	**46**
15	.19509	.19891	5.0273	.98079	**45**
16	.19538	.19921	5.0197	.98073	**44**
17	.19566	.19952	5.0121	.98067	**43**
18	.19595	.19982	5.0045	.98061	**42**
19	.19623	.20012	4.9969	.98056	**41**
20	.19652	.20042	4.9894	.98050	**40**
21	.19680	.20073	4.9819	.98044	**39**
22	.19709	.20103	4.9744	.98039	**38**
23	.19737	.20133	4.9669	.98033	**37**
24	.19766	.20164	4.9594	.98027	**36**
25	.19794	.20194	4.9520	.98021	**35**
26	.19823	.20224	4.9446	.98016	**34**
27	.19851	.20254	4.9372	.98010	**33**
28	.19880	.20285	4.9298	.98004	**32**
29	.19908	.20315	4.9225	.97998	**31**
30	.19937	.20345	4.9152	.97992	**30**
31	.19965	.20376	4.9078	.97987	**29**
32	.19994	.20406	4.9006	.97981	**28**
33	.20022	.20436	4.8933	.97975	**27**
34	.20051	.20466	4.8860	.97969	**26**
35	.20079	.20497	4.8788	.97963	**25**
36	.20108	.20527	4.8716	.97958	**24**
37	.20136	.20557	4.8644	.97952	**23**
38	.20165	.20588	4.8573	.97946	**22**
39	.20193	.20618	4.8501	.97940	**21**
40	.20222	.20648	4.8430	.97934	**20**
41	.20250	.20679	4.8359	.97928	**19**
42	.20279	.20709	4.8288	.97922	**18**
43	.20307	.20739	4.8218	.97916	**17**
44	.20336	.20770	4.8147	.97910	**16**
45	.20364	.20800	4.8077	.97905	**15**
46	.20393	.20830	4.8007	.97899	**14**
47	.20421	.20861	4.7937	.97893	**13**
48	.20450	.20891	4.7867	.97887	**12**
49	.20478	.20921	4.7798	.97881	**11**
50	.20507	.20952	4.7729	.97875	**10**
51	.20535	.20982	4.7659	.97869	**9**
52	.20563	.21013	4.7591	.97863	**8**
53	.20592	.21043	4.7522	.97857	**7**
54	.20620	.21073	4.7453	.97851	**6**
55	.20649	.21104	4.7385	.97845	**5**
56	.20677	.21134	4.7317	.97839	**4**
57	.20706	.21164	4.7249	.97833	**3**
58	.20734	.21195	4.7181	.97827	**2**
59	.20763	.21225	4.7114	.97821	**1**
60	.20791	.21256	4.7046	.97815	**0**
′	Cos	Cot	Tan	Sin	′

101°(281°) (258°)**78°**

NATURAL FUNCTIONS (Continued)

12° (192°) (347°) **167°**

′	Sin	Tan	Cot	Cos	′
0	.20791	.21256	4.7046	.97815	**60**
1	.20820	.21286	4.6979	.97809	59
2	.20848	.21316	4.6912	.97803	58
3	.20877	.21347	4.6845	.97797	57
4	.20905	.21377	4.6779	.97791	56
5	.20933	.21408	4.6712	.97784	**55**
6	.20962	.21438	4.6646	.97778	54
7	.20990	.21469	4.6580	.97772	53
8	.21019	.21499	4.6514	.97766	52
9	.21047	.21529	4.6448	.97760	51
10	.21076	.21560	4.6382	.97754	**50**
11	.21104	.21590	4.6317	.97748	49
12	.21132	.21621	4.6252	.97742	48
13	.21161	.21651	4.6187	.97735	47
14	.21189	.21682	4.6122	.97729	46
15	.21218	.21712	4.6057	.97723	**45**
16	.21246	.21743	4.5993	.97717	44
17	.21275	.21773	4.5928	.97711	43
18	.21303	.21804	4.5864	.97705	42
19	.21331	.21834	4.5800	.97698	41
20	.21360	.21864	4.5736	.97692	**40**
21	.21388	.21895	4.5673	.97686	39
22	.21417	.21925	4.5609	.97680	38
23	.21445	.21956	4.5546	.97673	37
24	.21474	.21986	4.5483	.97667	36
25	.21502	.22017	4.5420	.97661	**35**
26	.21530	.22047	4.5357	.97655	34
27	.21559	.22078	4.5294	.97648	33
28	.21587	.22108	4.5232	.97642	32
29	.21616	.22139	4.5169	.97636	31
30	.21644	.22169	4.5107	.97630	**30**
31	.21672	.22200	4.5045	.97623	29
32	.21701	.22231	4.4983	.97617	28
33	.21729	.22261	4.4922	.97611	27
34	.21758	.22292	4.4860	.97604	26
35	.21786	.22322	4.4799	.97598	**25**
36	.21814	.22353	4.4737	.97592	24
37	.21843	.22383	4.4676	.97585	23
38	.21871	.22414	4.4615	.97579	22
39	.21899	.22444	4.4555	.97573	21
40	.21928	.22475	4.4494	.97566	**20**
41	.21956	.22505	4.4434	.97560	19
42	.21985	.22536	4.4373	.97553	18
43	.22013	.22567	4.4313	.97547	17
44	.22041	.22597	4.4253	.97541	16
45	.22070	.22628	4.4194	.97534	**15**
46	.22098	.22658	4.4134	.97528	14
47	.22126	.22689	4.4075	.97521	13
48	.22155	.22719	4.4015	.97515	12
49	.22183	.22750	4.3956	.97508	11
50	.22212	.22781	4.3897	.97502	**10**
51	.22240	.22811	4.3838	.97496	9
52	.22268	.22842	4.3779	.97489	8
53	.22297	.22872	4.3721	.97483	7
54	.22325	.22903	4.3662	.97476	6
55	.22353	.22934	4.3604	.97470	**5**
56	.22382	.22964	4.3546	.97463	4
57	.22410	.22995	4.3488	.97457	3
58	.22438	.23026	4.3430	.97450	2
59	.22467	.23056	4.3372	.97444	1
60	.22495	.23087	4.3315	.97437	**0**
′	Cos	Cot	Tan	Sin	′

102° (282°) (257°) **77°**

13° (193°) (346°) **166°**

′	Sin	Tan	Cot	Cos	′
0	.22495	.23087	4.3315	.97437	**60**
1	.22523	.23117	4.3257	.97430	59
2	.22552	.23148	4.3200	.97424	58
3	.22580	.23179	4.3143	.97417	57
4	.22608	.23209	4.3086	.97411	56
5	.22637	.23240	4.3029	.97404	**55**
6	.22665	.23271	4.2972	.97398	54
7	.22693	.23301	4.2916	.97391	53
8	.22722	.23332	4.2859	.97384	52
9	.22750	.23363	4.2803	.97378	51
10	.22778	.23393	4.2747	.97371	**50**
11	.22807	.23424	4.2691	.97365	49
12	.22835	.23455	4.2635	.97358	48
13	.22863	.23485	4.2580	.97351	47
14	.22892	.23516	4.2524	.97345	46
15	.22920	.23547	4.2468	.97338	**45**
16	.22948	.23578	4.2413	.97331	44
17	.22977	.23608	4.2358	.97325	43
18	.23005	.23639	4.2303	.97318	42
19	.23033	.23670	4.2248	.97311	41
20	.23062	.23700	4.2193	.97304	**40**
21	.23090	.23731	4.2139	.97298	39
22	.23118	.23762	4.2084	.97291	38
23	.23146	.23793	4.2030	.97284	37
24	.23175	.23823	4.1976	.97278	36
25	.23203	.23854	4.1922	.97271	**35**
26	.23231	.23885	4.1868	.97264	34
27	.23260	.23916	4.1814	.97257	33
28	.23288	.23946	4.1760	.97251	32
29	.23316	.23977	4.1706	.97244	31
30	.23345	.24008	4.1653	.97237	**30**
31	.23373	.24039	4.1600	.97230	29
32	.23401	.24069	4.1547	.97223	28
33	.23429	.24100	4.1493	.97217	27
34	.23458	.24131	4.1441	.97210	26
35	.23486	.24162	4.1388	.97203	**25**
36	.23514	.24193	4.1335	.97196	24
37	.23542	.24223	4.1282	.97189	23
38	.23571	.24254	4.1230	.97182	22
39	.23599	.24285	4.1178	.97176	21
40	.23627	.24316	4.1126	.97169	**20**
41	.23656	.24347	4.1074	.97162	19
42	.23684	.24377	4.1022	.97155	18
43	.23712	.24408	4.0970	.97148	17
44	.23740	.24439	4.0918	.97141	16
45	.23769	.24470	4.0867	.97134	**15**
46	.23797	.24501	4.0815	.97127	14
47	.23825	.24532	4.0764	.97120	13
48	.23853	.24562	4.0713	.97113	12
49	.23882	.24593	4.0662	.97106	11
50	.23910	.24624	4.0611	.97100	**10**
51	.23938	.24655	4.0560	.97093	9
52	.23966	.24686	4.0509	.97086	8
53	.23995	.24717	4.0459	.97079	7
54	.24023	.24747	4.0408	.97072	6
55	.24051	.24778	4.0358	.97065	**5**
56	.24079	.24809	4.0308	.97058	4
57	.24108	.24840	4.0257	.97051	3
58	.24136	.24871	4.0207	.97044	2
59	.24164	.24902	4.0158	.97037	1
60	.24192	.24933	4.0108	.97030	**0**
′	Cos	Cot	Tan	Sin	′

103° (283°) (256°) **76°**

NATURAL FUNCTIONS (Continued)

14° (194°) (345°) **165°**

′	Sin	Tan	Cot	Cos	′
0	.24192	.24933	4.0108	.97030	**60**
1	.24220	.24964	4.0058	.97023	59
2	.24249	.24995	4.0009	.97015	58
3	.24277	.25026	3.9959	.97008	57
4	.24305	.25056	3.9910	.97001	56
5	.24333	.25087	3.9861	.96994	**55**
6	.24362	.25118	3.9812	.96987	54
7	.24390	.25149	3.9763	.96980	53
8	.24418	.25180	3.9714	.96973	52
9	.24446	.25211	3.9665	.96966	51
10	.24474	.25242	3.9617	.96959	**50**
11	.24503	.25273	3.9568	.96952	49
12	.24531	.25304	3.9520	.96945	48
13	.24559	.25335	3.9471	.96937	47
14	.24587	.25366	3.9423	.96930	46
15	.24615	.25397	3.9375	.96923	**45**
16	.24644	.25428	3.9327	.96916	44
17	.24672	.25459	3.9279	.96909	43
18	.24700	.25490	3.9232	.96902	42
19	.24728	.25521	3.9184	.96894	41
20	.24756	.25552	3.9136	.96887	**40**
21	.24784	.25583	3.9089	.96880	39
22	.24813	.25614	3.9042	.96873	38
23	.24841	.25645	3.8995	.96866	37
24	.24869	.25676	3.8947	.96858	36
25	.24897	.25707	3.8900	.96851	**35**
26	.24925	.25738	3.8854	.96844	34
27	.24954	.25769	3.8807	.96837	33
28	.24982	.25800	3.8760	.96829	32
29	.25010	.25831	3.8714	.96822	31
30	.25038	.25862	3.8667	.96815	**30**
31	.25066	.25893	3.8621	.96807	29
32	.25094	.25924	3.8575	.96800	28
33	.25122	.25955	3.8528	.96793	27
34	.25151	.25986	3.8482	.96786	26
35	.25179	.26017	3.8436	.96778	**25**
36	.25207	.26048	3.8391	.96771	24
37	.25235	.26079	3.8345	.96764	23
38	.25263	.26110	3.8299	.96756	22
39	.25291	.26141	3.8254	.96749	21
40	.25320	.26172	3.8208	.96742	**20**
41	.25348	.26203	3.8163	.96734	19
42	.25376	.26235	3.8118	.96727	18
43	.25404	.26266	3.8073	.96719	17
44	.25432	.26297	3.8028	.96712	16
45	.25460	.26328	3.7983	.96705	**15**
46	.25488	.26359	3.7938	.96697	14
47	.25516	.26390	3.7893	.96690	13
48	.25545	.26421	3.7848	.96682	12
49	.25573	.26452	3.7804	.96675	11
50	.25601	.26483	3.7760	.96667	**10**
51	.25629	.26515	3.7715	.96660	9
52	.25657	.26546	3.7671	.96653	8
53	.25685	.26577	3.7627	.96645	7
54	.25713	.26608	3.7583	.96638	6
55	.25741	.26639	3.7539	.96630	**5**
56	.25769	.26670	3.7495	.96623	4
57	.25798	.26701	3.7451	.96615	3
58	.25826	.26733	3.7408	.96608	2
59	.25854	.26764	3.7364	.96600	1
60	.25882	.26795	3.7321	.96593	**0**
′	Cos	Cot	Tan	Sin	′

104° (284°) (255°) **75°**

15° (195°) (344°) **164°**

′	Sin	Tan	Cot	Cos	′
0	.25882	.26795	3.7321	.96593	**60**
1	.25910	.26826	3.7277	.96585	59
2	.25938	.26857	3.7234	.96578	58
3	.25966	.26888	3.7191	.96570	57
4	.25994	.26920	3.7148	.96562	56
5	.26022	.26951	3.7105	.96555	**55**
6	.26050	.26982	3.7062	.96547	54
7	.26079	.27013	3.7019	.96540	53
8	.26107	.27044	3.6976	.96532	52
9	.26135	.27076	3.6933	.96524	51
10	.26163	.27107	3.6891	.96517	**50**
11	.26191	.27138	3.6848	.96509	49
12	.26219	.27169	3.6806	.96502	48
13	.26247	.27201	3.6764	.96494	47
14	.26275	.27232	3.6722	.96486	46
15	.26303	.27263	3.6680	.96479	**45**
16	.26331	.27294	3.6638	.96471	44
17	.26359	.27326	3.6596	.96463	43
18	.26387	.27357	3.6554	.96456	42
19	.26415	.27388	3.6512	.96448	41
20	.26443	.27419	3.6470	.96440	**40**
21	.26471	.27451	3.6429	.96433	39
22	.26500	.27482	3.6387	.96425	38
23	.26528	.27513	3.6346	.96417	37
24	.26556	.27545	3.6305	.96410	36
25	.26584	.27576	3.6264	.96402	**35**
26	.26612	.27607	3.6222	.96394	34
27	.26640	.27638	3.6181	.96386	33
28	.26668	.27670	3.6140	.96379	32
29	.26696	.27701	3.6100	.96371	31
30	.26724	.27732	3.6059	.96363	**30**
31	.26752	.27764	3.6018	.96355	29
32	.26780	.27795	3.5978	.96347	28
33	.26808	.27826	3.5937	.96340	27
34	.26836	.27858	3.5897	.96332	26
35	.26864	.27889	3.5856	.96324	**25**
36	.26892	.27921	3.5816	.96316	24
37	.26920	.27952	3.5776	.96308	23
38	.26948	.27983	3.5736	.96301	22
39	.26976	.28015	3.5696	.96293	21
40	.27004	.28046	3.5656	.96285	**20**
41	.27032	.28077	3.5616	.96277	19
42	.27060	.28109	3.5576	.96269	18
43	.27088	.28140	3.5536	.96261	17
44	.27116	.28172	3.5497	.96253	16
45	.27144	.28203	3.5457	.96246	**15**
46	.27172	.28234	3.5418	.96238	14
47	.27200	.28266	3.5379	.96230	13
48	.27228	.28297	3.5339	.96222	12
49	.27256	.28329	3.5300	.96214	11
50	.27284	.28360	3.5261	.96206	**10**
51	.27312	.28391	3.5222	.96198	9
52	.27340	.28423	3.5183	.96190	8
53	.27368	.28454	3.5144	.96182	7
54	.27396	.28486	3.5105	.96174	6
55	.27424	.28517	3.5067	.96166	**5**
56	.27452	.28549	3.5028	.96158	4
57	.27480	.28580	3.4989	.96150	3
58	.27508	.28612	3.4951	.96142	2
59	.27536	.28643	3.4912	.96134	1
60	.27564	.28675	3.4874	.96126	**0**
′	Cos	Cot	Tan	Sin	′

105° (285°) (254°) **74°**

NATURAL FUNCTIONS (Continued)

16° (196°) (343°) **163°**

′	Sin	Tan	Cot	Cos	′
0	.27564	.28675	3.4874	.96126	**60**
1	.27592	.28706	3.4836	.96118	59
2	.27620	.28738	3.4798	.96110	58
3	.27648	.28769	3.4760	.96102	57
4	.27676	.28801	3.4722	.96094	56
5	.27704	.28832	3.4684	.96086	**55**
6	.27731	.28864	3.4646	.96078	54
7	.27759	.28895	3.4608	.96070	53
8	.27787	.28927	3.4570	.96062	52
9	.27815	.28958	3.4533	.96054	51
10	.27843	.28990	3.4495	.96046	**50**
11	.27871	.29021	3.4458	.96037	49
12	.27899	.29053	3.4420	.96029	48
13	.27927	.29084	3.4383	.96021	47
14	.27955	.29116	3.4346	.96013	46
15	.27983	.29147	3.4308	.96005	**45**
16	.28011	.29179	3.4271	.95997	44
17	.28039	.29210	3.4234	.95989	43
18	.28067	.29242	3.4197	.95981	42
19	.28095	.29274	3.4160	.95972	41
20	.28123	.29305	3.4124	.95964	**40**
21	.28150	.29337	3.4087	.95956	39
22	.28178	.29368	3.4050	.95948	38
23	.28206	.29400	3.4014	.95940	37
24	.28234	.29432	3.3977	.95931	36
25	.28262	.29463	3.3941	.95923	**35**
26	.28290	.29495	3.3904	.95915	34
27	.28318	.29526	3.3868	.95907	33
28	.28346	.29558	3.3832	.95898	32
29	.28374	.29590	3.3796	.95890	31
30	.28402	.29621	3.3759	.95882	**30**
31	.28429	.29653	3.3723	.95874	29
32	.28457	.29685	3.3687	.95865	28
33	.28485	.29716	3.3652	.95857	27
34	.28513	.29748	3.3616	.95849	26
35	.28541	.29780	3.3580	.95841	**25**
36	.28569	.29811	3.3544	.95832	24
37	.28597	.29843	3.3509	.95824	23
38	.28625	.29875	3.3473	.95816	22
39	.28652	.29906	3.3438	.95807	21
40	.28680	.29938	3.3402	.95799	**20**
41	.28708	.29970	3.3367	.95791	19
42	.28736	.30001	3.3332	.95782	18
43	.28764	.30033	3.3297	.95774	17
44	.28792	.30065	3.3261	.95766	16
45	.28820	.30097	3.3226	.95757	**15**
46	.28847	.30128	3.3191	.95749	14
47	.28875	.30160	3.3156	.95740	13
48	.28903	.30192	3.3122	.95732	12
49	.28931	.30224	3.3087	.95724	11
50	.28959	.30255	3.3052	.95715	**10**
51	.28987	.30287	3.3017	.95707	9
52	.29015	.30319	3.2983	.95698	8
53	.29042	.30351	3.2948	.95690	7
54	.29070	.30382	3.2914	.95681	6
55	.29098	.30414	3.2879	.95673	**5**
56	.29126	.30446	3.2845	.95664	4
57	.29154	.30478	3.2811	.95656	3
58	.29182	.30509	3.2777	.95647	2
59	.29209	.30541	3.2743	.95639	1
60	.29237	.30573	3.2709	.95630	**0**
′	Cos	Cot	Tan	Sin	′

106° (286°) (253°) **73°**

17° (197°) (342°) **162°**

′	Sin	Tan	Cot	Cos	′
0	.29237	.30573	3.2709	.95630	**60**
1	.29265	.30605	3.2675	.95622	59
2	.29293	.30637	3.2641	.95613	58
3	.29321	.30669	3.2607	.95605	57
4	.29348	.30700	3.2573	.95596	56
5	.29376	.30732	3.2539	.95588	**55**
6	.29404	.30764	3.2506	.95579	54
7	.29432	.30796	3.2472	.95571	53
8	.29460	.30828	3.2438	.95562	52
9	.29487	.30860	3.2405	.95554	51
10	.29515	.30891	3.2371	.95545	**50**
11	.29543	.30923	3.2338	.95536	49
12	.29571	.30955	3.2305	.95528	48
13	.29599	.30987	3.2272	.95519	47
14	.29626	.31019	3.2238	.95511	46
15	.29654	.31051	3.2205	.95502	**45**
16	.29682	.31083	3.2172	.95493	44
17	.29710	.31115	3.2139	.95485	43
18	.29737	.31147	3.2106	.95476	42
19	.29765	.31178	3.2073	.95467	41
20	.29793	.31210	3.2041	.95459	**40**
21	.29821	.31242	3.2008	.95450	39
22	.29849	.31274	3.1975	.95441	38
23	.29876	.31306	3.1943	.95433	37
24	.29904	.31338	3.1910	.95424	36
25	.29932	.31370	3.1878	.95415	**35**
26	.29960	.31402	3.1845	.95407	34
27	.29987	.31434	3.1813	.95398	33
28	.30015	.31466	3.1780	.95389	32
29	.30043	.31498	3.1748	.95380	31
30	.30071	.31530	3.1716	.95372	**30**
31	.30098	.31562	3.1684	.95363	29
32	.30126	.31594	3.1652	.95354	28
33	.30154	.31626	3.1620	.95345	27
34	.30182	.31658	3.1588	.95337	26
35	.30209	.31690	3.1556	.95328	**25**
36	.30237	.31722	3.1524	.95319	24
37	.30265	.31754	3.1492	.95310	23
38	.30292	.31786	3.1460	.95301	22
39	.30320	.31818	3.1429	.95293	21
40	.30348	.31850	3.1397	.95284	**20**
41	.30376	.31882	3.1366	.95275	19
42	.30403	.31914	3.1334	.95266	18
43	.30431	.31946	3.1303	.95257	17
44	.30459	.31978	3.1271	.95248	16
45	.30486	.32010	3.1240	.95240	**15**
46	.30514	.32042	3.1209	.95231	14
47	.30542	.32074	3.1178	.95222	13
48	.30570	.32106	3.1146	.95213	12
49	.30597	.32139	3.1115	.95204	11
50	.30625	.32171	3.1084	.95195	**10**
51	.30653	.32203	3.1053	.95186	9
52	.30680	.32235	3.1022	.95177	8
53	.30708	.32267	3.0991	.95168	7
54	.30736	.32299	3.0961	.95159	6
55	.30763	.32331	3.0930	.95150	**5**
56	.30791	.32363	3.0899	.95142	4
57	.30819	.32396	3.0868	.95133	3
58	.30846	.32428	3.0838	.95124	2
59	.30874	.32460	3.0807	.95115	1
60	.30902	.32492	3.0777	.95106	**0**
′	Cos	Cot	Tan	Sin	′

107° (287°) (252°) **72°**

NATURAL FUNCTIONS (Continued)

18° (198°) (341°) **161°**

′	Sin	Tan	Cot	Cos	′
0	.30902	.32492	3.0777	.95106	**60**
1	.30929	.32524	3.0746	.95097	59
2	.30957	.32556	3.0716	.95088	58
3	.30985	.32588	3.0686	.95079	57
4	.31012	.32621	3.0655	.95070	56
5	.31040	.32653	3.0625	.95061	**55**
6	.31068	.32685	3.0595	.95052	54
7	.31095	.32717	3.0565	.95043	53
8	.31123	.32749	3.0535	.95033	52
9	.31151	.32782	3.0505	.95024	51
10	.31178	.32814	3.0475	.95015	**50**
11	.31206	.32846	3.0445	.95006	49
12	.31233	.32878	3.0415	.94997	48
13	.31261	.32911	3.0385	.94988	47
14	.31289	.32943	3.0356	.94979	46
15	.31316	.32975	3.0326	.94970	**45**
16	.31344	.33007	3.0296	.94961	44
17	.31372	.33040	3.0267	.94952	43
18	.31399	.33072	3.0237	.94943	42
19	.31427	.33104	3.0208	.94933	41
20	.31454	.33136	3.0178	.94924	**40**
21	.31482	.33169	3.0149	.94915	39
22	.31510	.33201	3.0120	.94906	38
23	.31537	.33233	3.0090	.94897	37
24	.31565	.33266	3.0061	.94888	36
25	.31593	.33298	3.0032	.94878	**35**
26	.31620	.33330	3.0003	.94869	34
27	.31648	.33363	2.9974	.94860	33
28	.31675	.33395	2.9945	.94851	32
29	.31703	.33427	2.9916	.94842	31
30	.31730	.33460	2.9887	.94832	**30**
31	.31758	.33492	2.9858	.94823	29
32	.31786	.33524	2.9829	.94814	28
33	.31813	.33557	2.9800	.94805	27
34	.31841	.33589	2.9772	.94795	26
35	.31868	.33621	2.9743	.94786	**25**
36	.31896	.33654	2.9714	.94777	24
37	.31923	.33686	2.9686	.94768	23
38	.31951	.33718	2.9657	.94758	22
39	.31979	.33751	2.9629	.94749	21
40	.32006	.33783	2.9600	.94740	**20**
41	.32034	.33816	2.9572	.94730	19
42	.32061	.33848	2.9544	.94721	18
43	.32089	.33881	2.9515	.94712	17
44	.32116	.33913	2.9487	.94702	16
45	.32144	.33945	2.9459	.94693	**15**
46	.32171	.33978	2.9431	.94684	14
47	.32199	.34010	2.9403	.94674	13
48	.32227	.34043	2.9375	.94665	12
49	.32254	.34075	2.9347	.94656	11
50	.32282	.34108	2.9319	.94646	**10**
51	.32309	.34140	2.9291	.94637	9
52	.32337	.34173	2.9263	.94627	8
53	.32364	.34205	2.9235	.94618	7
54	.32392	.34238	2.9208	.94609	6
55	.32419	.34270	2.9180	.94599	**5**
56	.32447	.34303	2.9152	.94590	4
57	.32474	.34335	2.9125	.94580	3
58	.32502	.31368	2.9097	.94571	2
59	.32529	.34400	2.9070	.94561	1
60	.32557	.34433	2.9042	.94552	**0**
′	Cos	Cot	Tan	Sin	′

108° (288°) (251°) **71°**

19° (199°) (340°) **160°**

′	Sin	Tan	Cot	Cos	′
0	.32557	.34433	2.9042	.94552	**60**
1	.32584	.34465	2.9015	.94542	59
2	.32612	.34498	2.8987	.94533	58
3	.32639	.34530	2.8960	.94523	57
4	.32667	.34563	2.8933	.94514	56
5	.32694	.34596	2.8905	.94504	**55**
6	.32722	.34628	2.8878	.94495	54
7	.32749	.34661	2.8851	.94485	53
8	.32777	.34693	2.8824	.94476	52
9	.32804	.34726	2.8797	.94466	51
10	.32832	.34758	2.8770	.94457	**50**
11	.32859	.34791	2.8743	.94447	49
12	.32887	.34824	2.8716	.94438	48
13	.32914	.34856	2.8689	.94428	47
14	.32942	.34889	2.8662	.94418	46
15	.32969	.34922	2.8636	.94409	**45**
16	.32997	.34954	2.8609	.94399	44
17	.33024	.34987	2.8582	.94390	43
18	.33051	.35020	2.8556	.94380	42
19	.33079	.35052	2.8529	.94370	41
20	.33106	.35085	2.8502	.94361	**40**
21	.33134	.35118	2.8476	.94351	39
22	.33161	.35150	2.8449	.94342	38
23	.33189	.35183	2.8423	.94332	37
24	.33216	.35216	2.8397	.94322	36
25	.33244	.35248	2.8370	.94313	**35**
26	.33271	.35281	2.8344	.94303	34
27	.33298	.35314	2.8318	.94293	33
28	.33326	.35346	2.8291	.94284	32
29	.33353	.35379	2.8265	.94274	31
30	.33381	.35412	2.8239	.94264	**30**
31	.33408	.35445	2.8213	.94254	29
32	.33436	.35477	2.8187	.94245	28
33	.33463	.35510	2.8161	.94235	27
34	.33490	.35543	2.8135	.94225	26
35	.33518	.35576	2.8109	.94215	**25**
36	.33545	.35608	2.8083	.94206	24
37	.33573	.35641	2.8057	.94196	23
38	.33600	.35674	2.8032	.94186	22
39	.33627	.35707	2.8006	.94176	21
40	.33655	.35740	2.7980	.94167	**20**
41	.33682	.35772	2.7955	.94157	19
42	.33710	.35805	2.7929	.94147	18
43	.33737	.35838	2.7903	.94137	17
44	.33764	.35871	2.7878	.94127	16
45	.33792	.35904	2.7852	.94118	**15**
46	.33819	.35937	2.7827	.94108	14
47	.33846	.35969	2.7801	.94098	13
48	.33874	.36002	2.7776	.94088	12
49	.33901	.36035	2.7751	.94078	11
50	.33929	.36068	2.7725	.94068	**10**
51	.33956	.36101	2.7700	.94058	**9**
52	.33983	.36134	2.7675	.94049	**8**
53	.34011	.36167	2.7650	.94039	**7**
54	.34038	.36199	2.7625	.94029	**6**
55	.34065	.36232	2.7600	.94019	**5**
56	.34093	.36265	2.7575	.94009	**4**
57	.34120	.36298	2.7550	.93999	**3**
58	.34147	.36331	2.7525	.93989	**2**
59	.34175	.36364	2.7500	.93979	**1**
60	.34202	.36397	2.7475	.93969	**0**
′	Cos	Cot	Tan	Sin	′

109° (289°) (250°) **70°**

NATURAL FUNCTIONS (Continued)

20° (200°) (339°) **159°**

′	Sin	Tan	Cot	Cos	′
0	.34202	.36397	2.7475	.93969	**60**
1	.34229	.36430	2.7450	.93959	59
2	.34257	.36463	2.7425	.93949	58
3	.34284	.36496	2.7400	.93939	57
4	.34311	.36529	2.7376	.93929	56
5	.34339	.36562	2.7351	.93919	**55**
6	.34366	.36595	2.7326	.93909	54
7	.34393	.36628	2.7302	.93899	53
8	.34421	.36661	2.7277	.93889	52
9	.34448	.36694	2.7253	.93879	51
10	.34475	.36727	2.7228	.93869	**50**
11	.34503	.36760	2.7204	.93859	49
12	.34530	.36793	2.7179	.93849	48
13	.34557	.36826	2.7155	.93839	47
14	.34584	.36859	2.7130	.93829	46
15	.34612	.36892	2.7106	.93819	**45**
16	.34639	.36925	2.7082	.93809	44
17	.34666	.36958	2.7058	.93799	43
18	.34694	.36991	2.7034	.93789	42
19	.34721	.37024	2.7009	.93779	41
20	.34748	.37057	2.6985	.93769	**40**
21	.34775	.37090	2.6961	.93759	39
22	.34803	.37123	2.6937	.93748	38
23	.34830	.37157	2.6913	.93738	37
24	.34857	.37190	2.6889	.93728	36
25	.34884	.37223	2.6865	.93718	**35**
26	.34912	.37256	2.6841	.93708	34
27	.34939	.37289	2.6818	.93698	33
28	.34966	.37322	2.6794	.93688	32
29	.34993	.37355	2.6770	.93677	31
30	.35021	.37388	2.6746	.93667	**30**
31	.35048	.37422	2.6723	.93657	29
32	.35075	.37455	2.6699	.93647	28
33	.35102	.37488	2.6675	.93637	27
34	.35130	.37521	2.6652	.93626	26
35	.35157	.37554	2.6628	.93616	**25**
36	.35184	.37588	2.6605	.93606	24
37	.35211	.37621	2.6581	.93596	23
38	.35239	.37654	2.6558	.93585	22
39	.35266	.37687	2.6534	.93575	21
40	.35293	.37720	2.6511	.93565	**20**
41	.35320	.37754	2.6488	.93555	19
42	.35347	.37787	2.6464	.93544	18
43	.35375	.37820	2.6441	.93534	17
44	.35402	.37853	2.6418	.93524	16
45	.35429	.37887	2.6395	.93514	**15**
46	.35456	.37920	2.6371	.93503	14
47	.35484	.37953	2.6348	.93493	13
48	.35511	.37986	2.6325	.93483	12
49	.35538	.38020	2.6302	.93472	11
50	.35565	.38053	2.6279	.93462	**10**
51	.35592	.38086	2.6256	.93452	9
52	.35619	.38120	2.6233	.93441	8
53	.35647	.38153	2.6210	.93431	7
54	.35674	.38186	2.6187	.93420	6
55	.35701	.38220	2.6165	.93410	**5**
56	.35728	.38253	2.6142	.93400	4
57	.35755	.38286	2.6119	.93389	3
58	.35782	.38320	2.6096	.93379	2
59	.35810	.38353	2.6074	.93368	1
60	.35837	.38386	2.6051	.93358	**0**
′	Cos	Cot	Tan	Sin	′

110° (290°) (249°) **69°**

21° (201°) (338°) **158°**

′	Sin	Tan	Cot	Cos	′
0	.35837	.38386	2.6051	.93358	**60**
1	.35864	.38420	2.6028	.93348	59
2	.35891	.38453	2.6006	.93337	58
3	.35918	.38487	2.5983	.93327	57
4	.35945	.38520	2.5961	.93316	56
5	.35973	.38553	2.5938	.93306	**55**
6	.36000	.38587	2.5916	.93295	54
7	.36027	.38620	2.5893	.93285	53
8	.36054	.38654	2.5871	.93274	52
9	.36081	.38687	2.5848	.93264	51
10	.36108	.38721	2.5826	.93253	**50**
11	.36135	.38754	2.5804	.93243	49
12	.36162	.38787	2.5782	.93232	48
13	.36190	.38821	2.5759	.93222	47
14	.36217	.38854	2.5737	.93211	46
15	.36244	.38888	2.5715	.93201	**45**
16	.36271	.38921	2.5693	.93190	44
17	.36298	.38955	2.5671	.93180	43
18	.36325	.38988	2.5649	.93169	42
19	.36352	.39022	2.5627	.93159	41
20	.36379	.39055	2.5605	.93148	**40**
21	.36406	.39089	2.5583	.93137	39
22	.36434	.39122	2.5561	.93127	38
23	.36461	.39156	2.5539	.93116	37
24	.36488	.39190	2.5517	.93106	36
25	.36515	.39223	2.5495	.93095	**35**
26	.36542	.39257	2.5473	.93084	34
27	.36569	.39290	2.5452	.93074	33
28	.36596	.39324	2.5430	.93063	32
29	.36623	.39357	2.5408	.93052	31
30	.36650	.39391	2.5386	.93042	**30**
31	.36677	.39425	2.5365	.93031	29
32	.36704	.39458	2.5343	.93020	28
33	.36731	.39492	2.5322	.93010	27
34	.36758	.39526	2.5300	.92999	26
35	.36785	.39559	2.5279	.92988	**25**
36	.36812	.39593	2.5257	.92978	24
37	.36839	.39626	2.5236	.92967	23
38	.36867	.39660	2.5214	.92956	22
39	.36894	.39694	2.5193	.92945	21
40	.36921	.39727	2.5172	.92935	**20**
41	.36948	.39761	2.5150	.92924	19
42	.36975	.39795	2.5129	.92913	18
43	.37002	.39829	2.5108	.92902	17
44	.37029	.39862	2.5086	.92892	16
45	.37056	.39896	2.5065	.92881	**15**
46	.37083	.39930	2.5044	.92870	14
47	.37110	.39963	2.5023	.92859	13
48	.37137	.39997	2.5002	.92849	12
49	.37164	.40031	2.4981	.92838	11
50	.37191	.40065	2.4960	.92827	**10**
51	.37218	.40098	2.4939	.92816	9
52	.37245	.40132	2.4918	.92805	8
53	.37272	.40166	2.4897	.92794	7
54	.37299	.40200	2.4876	.92784	6
55	.37326	.40234	2.4855	.92773	**5**
56	.37353	.40267	2.4834	.92762	4
57	.37380	.40301	2.4813	.92751	3
58	.37407	.40335	2.4792	.92740	2
59	.37434	.40369	2.4772	.92729	1
60	.37461	.40403	2.4751	.92718	**0**
′	Cos	Cot	Tan	Sin	′

111° (291°) (248°) **68°**

NATURAL FUNCTIONS (Continued)

22° (202°) (337°) **157°**

′	Sin	Tan	Cot	Cos	′
0	.37461	.40403	2.4751	.92718	**60**
1	.37488	.40436	2.4730	.92707	59
2	.37515	.40470	2.4709	.92697	58
3	.37542	.40504	2.4689	.92686	57
4	.37569	.40538	2.4668	.92675	56
5	.37595	.40572	2.4648	.92664	**55**
6	.37622	.40606	2.4627	.92653	54
7	.37649	.40640	2.4606	.92642	53
8	.37676	.40674	2.4586	.92631	52
9	.37703	.40707	2.4566	.92620	51
10	.37730	.40741	2.4545	.92609	**50**
11	.37757	.40775	2.4525	.92598	49
12	.37784	.40809	2.4504	.92587	48
13	.37811	.40843	2.4484	.92576	47
14	.37838	.40877	2.4464	.92565	46
15	.37865	.40911	2.4443	.92554	**45**
16	.37892	.40945	2.4423	.92543	44
17	.37919	.40979	2.4403	.92532	43
18	.37946	.41013	2.4383	.92521	42
19	.37973	.41047	2.4362	.92510	41
20	.37999	.41081	2.4342	.92499	**40**
21	.38026	.41115	2.4322	.92488	39
22	.38053	.41149	2.4302	.92477	38
23	.38080	.41183	2.4282	.92466	37
24	.38107	.41217	2.4262	.92455	36
25	.38134	.41251	2.4242	.92444	**35**
26	.38161	.41285	2.4222	.92432	34
27	.38188	.41319	2.4202	.92421	33
28	.38215	.41353	2.4182	.92410	32
29	.38241	.41387	2.4162	.92399	31
30	.38268	.41421	2.4142	.92388	**30**
31	.38295	.41455	2.4122	.92377	29
32	.38322	.41490	2.4102	.92366	28
33	.38349	.41524	2.4083	.92355	27
34	.38376	.41558	2.4063	.92343	26
35	.38403	.41592	2.4043	.92332	**25**
36	.38430	.41626	2.4023	.92321	24
37	.38456	.41660	2.4004	.92310	23
38	.38483	.41694	2.3984	.92299	22
39	.38510	.41728	2.3964	.92287	21
40	.38537	.41763	2.3945	.92276	**20**
41	.38564	.41797	2.3925	.92265	19
42	.38591	.41831	2.3906	.92254	18
43	.38617	.41865	2.3886	.92243	17
44	.38644	.41899	2.3867	.92231	16
45	.38671	.41933	2.3847	.92220	**15**
46	.38698	.41968	2.3828	.92209	14
47	.38725	.42002	2.3808	.92198	13
48	.38752	.42036	2.3789	.92186	12
49	.38778	.42070	2.3770	.92175	11
50	.38805	.42105	2.3750	.92164	**10**
51	.38832	.42139	2.3731	.92152	9
52	.38859	.42173	2.3712	.92141	8
53	.38886	.42207	2.3693	.92130	7
54	.38912	.42242	2.3673	.92119	6
55	.38939	.42276	2.3654	.92107	**5**
56	.38966	.42310	2.3635	.92096	4
57	.38993	.42345	2.3616	.92085	3
58	.39020	.42379	2.3597	.92073	2
59	.39046	.42413	2.3578	.92062	1
60	.39073	.42447	2.3559	.92050	**0**
′	Cos	Cot	Tan	Sin	′

112° (292°) (247°) **67°**

23° (203°) (336°) **156°**

′	Sin	Tan	Cot	Cos	′
0	.39073	.42447	2.3559	.92050	**60**
1	.39100	.42482	2.3539	.92039	59
2	.39127	.42516	2.3520	.92028	58
3	.39153	.42551	2.3501	.92016	57
4	.39180	.42585	2.3483	.92005	56
5	.39207	.42619	2.3464	.91994	**55**
6	.39234	.42654	2.3445	.91982	54
7	.39260	.42688	2.3426	.91971	53
8	.39287	.42722	2.3407	.91959	52
9	.39314	.42757	2.3388	.91948	51
10	.39341	.42791	2.3369	.91936	**50**
11	.39367	.42826	2.3351	.91925	49
12	.39394	.42860	2.3332	.91914	48
13	.39421	.42894	2.3313	.91902	47
14	.39448	.42929	2.3294	.91891	46
15	.39474	.42963	2.3276	.91879	**45**
16	.39501	.42998	2.3257	.91868	44
17	.39528	.43032	2.3238	.91856	43
18	.39555	.43067	2.3220	.91845	42
19	.39581	.43101	2.3201	.91833	41
20	.39608	.43136	2.3183	.91822	**40**
21	.39635	.43170	2.3164	.91810	39
22	.39661	.43205	2.3146	.91799	38
23	.39688	.43239	2.3127	.91787	37
24	.39715	.43274	2.3109	.91775	36
25	.39741	.43308	2.3090	.91764	**35**
26	.39768	.43343	2.3072	.91752	34
27	.39795	.43378	2.3053	.91741	33
28	.39822	.43412	2.3035	.91729	32
29	.39848	.43447	2.3017	.91718	31
30	.39875	.43481	2.2998	.91706	**30**
31	.39902	.43516	2.2980	.91694	29
32	.39928	.43550	2.2962	.91683	28
33	.39955	.43585	2.2944	.91671	27
34	.39982	.43620	2.2925	.91660	26
35	.40008	.43654	2.2907	.91648	**25**
36	.40035	.43689	2.2889	.91636	24
37	.40062	.43724	2.2871	.91625	23
38	.40088	.43758	2.2853	.91613	22
39	.40115	.43793	2.2835	.91601	21
40	.40141	.43828	2.2817	.91590	**20**
41	.40168	.43862	2.2799	.91578	19
42	.40195	.43897	2.2781	.91566	18
43	.40221	.43932	2.2763	.91555	17
44	.40248	.43966	2.2745	.91543	16
45	.40275	.44001	2.2727	.91531	**15**
46	.40301	.44036	2.2709	.91519	14
47	.40328	.44071	2.2691	.91508	13
48	.40355	.44105	2.2673	.91496	12
49	.40381	.44140	2.2655	.91484	11
50	.40408	.44175	2.2637	.91472	**10**
51	.40434	.44210	2.2620	.91461	9
52	.40461	.44244	2.2602	.91449	8
53	.40488	.44279	2.2584	.91437	7
54	.40514	.44314	2.2566	.91425	6
55	.40541	.44349	2.2549	.91414	**5**
56	.40567	.44384	2.2531	.91402	4
57	.40594	.44418	2.2513	.91390	3
58	.40621	.44453	2.2496	.91378	2
59	.40647	.44488	2.2478	.91366	1
60	.40674	.44523	2.2460	.91355	**0**
′	Cos	Cot	Tan	Sin	

113° (293°) (246°) **66°**

NATURAL FUNCTIONS (Continued)

24° (204°) (335°) **155°**

′	Sin	Tan	Cot	Cos	′
0	.40674	.44523	2.2460	.91355	60
1	.40700	.44558	2.2443	.91343	59
2	.40727	.44593	2.2425	.91331	58
3	.40753	.44627	2.2408	.91319	57
4	.40780	.44662	2.2390	.91307	56
5	.40806	.44697	2.2373	.91295	55
6	.40833	.44732	2.2355	.91283	54
7	.40860	.44767	2.2338	.91272	53
8	.40886	.44802	2.2320	.91260	52
9	.40913	.44837	2.2303	.91248	51
10	.40939	.44872	2.2286	.91236	50
11	.40966	.44907	2.2268	.91224	49
12	.40992	.44942	2.2251	.91212	48
13	.41019	.44977	2.2234	.91200	47
14	.41045	.45012	2.2216	.91188	46
15	.41072	.45047	2.2199	.91176	45
16	.41098	.45082	2.2182	.91164	44
17	.41125	.45117	2.2165	.91152	43
18	.41151	.45152	2.2148	.91140	42
19	.41178	.45187	2.2130	.91128	41
20	.41204	.45222	2.2113	.91116	40
21	.41231	.45257	2.2096	.91104	39
22	.41257	.45292	2.2079	.91092	38
23	.41284	.45327	2.2062	.91080	37
24	.41310	.45362	2.2045	.91068	36
25	.41337	.45397	2.2028	.91056	35
26	.41363	.45432	2.2011	.91044	34
27	.41390	.45467	2.1994	.91032	33
28	.41416	.45502	2.1977	.91020	32
29	.41443	.45538	2.1960	.91008	31
30	.41469	.45573	2.1943	.90996	30
31	.41496	.45608	2.1926	.90984	29
32	.41522	.45643	2.1909	.90972	28
33	.41549	.45678	2.1892	.90960	27
34	.41575	.45713	2.1876	.90948	26
35	.41602	.45748	2.1859	.90936	25
36	.41628	.45784	2.1842	.90924	24
37	.41655	.45819	2.1825	.90911	23
38	.41681	.45854	2.1808	.90899	22
39	.41707	.45889	2.1792	.90887	21
40	.41734	.45924	2.1775	.90875	20
41	.41760	.45960	2.1758	.90863	19
42	.41787	.45995	2.1742	.90851	18
43	.41813	.46030	2.1725	.90839	17
44	.41840	.46065	2.1708	.90826	16
45	.41866	.46101	2.1692	.90814	15
46	.41892	.46136	2.1675	.90802	14
47	.41919	.46171	2.1659	.90790	13
48	.41945	.46206	2.1642	.90778	12
49	.41972	.46242	2.1625	.90766	11
50	.41998	.46277	2.1609	.90753	10
51	.42024	.46312	2.1592	.90741	9
52	.42051	.46348	2.1576	.90729	8
53	.42077	.46383	2.1560	.90717	7
54	.42104	.46418	2.1543	.90704	6
55	.42130	.46454	2.1527	.90692	5
56	.42156	.46489	2.1510	.90680	4
57	.42183	.46525	2.1494	.90668	3
58	.42209	.46560	2.1478	.90655	2
59	.42235	.46595	2.1461	.90643	1
60	.42262	.46631	2.1445	.90631	0
′	Cos	Cot	Tan	Sin	′

114° (294°) (245°) **65°**

25° (205°) (334°) **154°**

′	Sin	Tan	Cot	Cos	′
0	.42262	.46631	2.1445	.90631	60
1	.42288	.46666	2.1429	.90618	59
2	.42315	.46702	2.1413	.90606	58
3	.42341	.46737	2.1396	.90594	57
4	.42367	.46772	2.1380	.90582	56
5	.42394	.46808	2.1364	.90569	55
6	.42420	.46843	2.1348	.90557	54
7	.42446	.46879	2.1332	.90545	53
8	.42473	.46914	2.1315	.90532	52
9	.42499	.46950	2.1299	.90520	51
10	.42525	.46985	2.1283	.90507	50
11	.42552	.47021	2.1267	.90495	49
12	.42578	.47056	2.1251	.90483	48
13	.42604	.47092	2.1235	.90470	47
14	.42631	.47128	2.1219	.90458	46
15	.42657	.47163	2.1203	.90446	45
16	.42683	.47199	2.1187	.90433	44
17	.42709	.47234	2.1171	.90421	43
18	.42736	.47270	2.1155	.90408	42
19	.42762	.47305	2.1139	.90396	41
20	.42788	.47341	2.1123	.90383	40
21	.42815	.47377	2.1107	.90371	39
22	.42841	.47412	2.1092	.90358	38
23	.42867	.47448	2.1076	.90346	37
24	.42894	.47483	2.1060	.90334	36
25	.42920	.47519	2.1044	.90321	35
26	.42946	.47555	2.1028	.90309	34
27	.42972	.47590	2.1013	.90296	33
28	.42999	.47626	2.0997	.90284	32
29	.43025	.47662	2.0981	.90271	31
30	.43051	.47698	2.0965	.90259	30
31	.43077	.47733	2.0950	.90246	29
32	.43104	.47769	2.0934	.90233	28
33	.43130	.47805	2.0918	.90221	27
34	.43156	.47840	2.0903	.90208	26
35	.43182	.47876	2.0887	.90196	25
36	.43209	.47912	2.0872	.90183	24
37	.43235	.47948	2.0856	.90171	23
38	.43261	.47984	2.0840	.90158	22
39	.43287	.48019	2.0825	.90146	21
40	.43313	.48055	2.0809	.90133	20
41	.43340	.48091	2.0794	.90120	19
42	.43366	.48127	2.0778	.90108	18
43	.43392	.48163	2.0763	.90095	17
44	.43418	.48198	2.0748	.90082	16
45	.43445	.48234	2.0732	.90070	15
46	.43471	.48270	2.0717	.90057	14
47	.43497	.48306	2.0701	.90045	13
48	.43523	.48342	2.0686	.90032	12
49	.43549	.48378	2.0671	.90019	11
50	.43575	.48414	2.0655	.90007	10
51	.43602	.48450	2.0640	.89994	9
52	.43628	.48486	2.0625	.89981	8
53	.43654	.48521	2.0609	.89968	7
54	.43680	.48557	2.0594	.89956	6
55	.43706	.48593	2.0579	.89943	5
56	.43733	.48629	2.0564	.89930	4
57	.43759	.48665	2.0549	.89918	3
58	.43785	.48701	2.0533	.89905	2
59	.43811	.48737	2.0518	.89892	1
60	.43837	.48773	2.0503	.89879	0
′	Cos	Cot	Tan	Sin	′

115° (295°) (244°) **64°**

NATURAL FUNCTIONS (Continued)

26° (206°) (333°) **153°**

′	Sin	Tan	Cot	Cos	′
0	.43837	.48773	2.0503	.89879	60
1	.43863	.48809	2.0488	.89867	59
2	.43889	.48845	2.0473	.89854	58
3	.43916	.48881	2.0458	.89841	57
4	.43942	.48917	2.0443	.89828	56
5	.43968	.48953	2.0428	.89816	55
6	.43994	.48989	2.0413	.89803	54
7	.44020	.49026	2.0398	.89790	53
8	.44046	.49062	2.0383	.89777	52
9	.44072	.49098	2.0368	.89764	51
10	.44098	.49134	2.0353	.89752	50
11	.44124	.49170	2.0338	.89739	49
12	.44151	.49206	2.0323	.89726	48
13	.44177	.49242	2.0308	.89713	47
14	.44203	.49278	2.0293	.89700	46
15	.44229	.49315	2.0278	.89687	45
16	.44255	.49351	2.0263	.89674	44
17	.44281	.49387	2.0248	.89662	43
18	.44307	.49423	2.0233	.89649	42
19	.44333	.49459	2.0219	.89636	41
20	.44359	.49495	2.0204	.89623	40
21	.44385	.49532	2.0189	.89610	39
22	.44411	.49568	2.0174	.89597	38
23	.44437	.49604	2.0160	.89584	37
24	.44464	.49640	2.0145	.89571	36
25	.44490	.49677	2.0130	.89558	35
26	.44516	.49713	2.0115	.89545	34
27	.44542	.49749	2.0101	.89532	33
28	.44568	.49786	2.0086	.89519	32
29	.44594	.49822	2.0072	.89506	31
30	.44620	.49858	2.0057	.89493	30
31	.44646	.49894	2.0042	.89480	29
32	.44672	.49931	2.0028	.89467	28
33	.44698	.49967	2.0013	.89454	27
34	.44724	.50004	1.9999	.89441	26
35	.44750	.50040	1.9984	.89428	25
36	.44776	.50076	1.9970	.89415	24
37	.44802	.50113	1.9955	.89402	23
38	.44828	.50149	1.9941	.89389	22
39	.44854	.50185	1.9926	.89376	21
40	.44880	.50222	1.9912	.89363	20
41	.44906	.50258	1.9897	.89350	19
42	.44932	.50295	1.9883	.89337	18
43	.44958	.50331	1.9868	.89324	17
44	.44984	.50368	1.9854	.89311	16
45	.45010	.50404	1.9840	.89298	15
46	.45036	.50441	1.9825	.89285	14
47	.45062	.50477	1.9811	.89272	13
48	.45088	.50514	1.9797	.89259	12
49	.45114	.50550	1.9782	.89245	11
50	.45140	.50587	1.9768	.89232	10
51	.45166	.50623	1.9754	.89219	9
52	.45192	.50660	1.9740	.89206	8
53	.45218	.50696	1.9725	.89193	7
54	.45243	.50733	1.9711	.89180	6
55	.45269	.50769	1.9697	.89167	5
56	.45295	.50806	1.9683	.89153	4
57	.45321	.50843	1.9669	.89140	3
58	.45347	.50879	1.9654	.89127	2
59	.45373	.50916	1.9640	.89114	1
60	.45399	.50953	1.9626	.89101	0
′	Cos	Cot	Tan	Sin	′

116° (296°) (243°) **63°**

27° (207°) (332°) **152°**

′	Sin	Tan	Cot	Cos	′
0	.45399	.50953	1.9626	.89101	60
1	.45425	.50989	1.9612	.89087	59
2	.45451	.51026	1.9598	.89074	58
3	.45477	.51063	1.9584	.89061	57
4	.45503	.51099	1.9570	.89048	56
5	.45529	.51136	1.9556	.89035	55
6	.45554	.51173	1.9542	.89021	54
7	.45580	.51209	1.9528	.89008	53
8	.45606	.51246	1.9514	.88995	52
9	.45632	.51283	1.9500	.88981	51
10	.45658	.51319	1.9486	.88968	50
11	.45684	.51356	1.9472	.88955	49
12	.45710	.51393	1.9458	.88942	48
13	.45736	.51430	1.9444	.88928	47
14	.45762	.51467	1.9430	.88915	46
15	.45787	.51503	1.9416	.88902	45
16	.45813	.51540	1.9402	.88888	44
17	.45839	.51577	1.9388	.88875	43
18	.45865	.51614	1.9375	.88862	42
19	.45891	.51651	1.9361	.88848	41
20	.45917	.51688	1.9347	.88835	40
21	.45942	.51724	1.9333	.88822	39
22	.45968	.51761	1.9319	.88808	38
23	.45994	.51798	1.9306	.88795	37
24	.46020	.51835	1.9292	.88782	36
25	.46046	.51872	1.9278	.88768	35
26	.46072	.51909	1.9265	.88755	34
27	.46097	.51946	1.9251	.88741	33
28	.46123	.51983	1.9237	.88728	32
29	.46149	.52020	1.9223	.88715	31
30	.46175	.52057	1.9210	.88701	30
31	.46201	.52094	1.9196	.88688	29
32	.46226	.52131	1.9183	.88674	28
33	.46252	.52168	1.9169	.88661	27
34	.46278	.52205	1.9155	.88647	26
35	.46304	.52242	1.9142	.88634	25
36	.46330	.52279	1.9128	.88620	24
37	.46355	.52316	1.9115	.88607	23
38	.46381	.52353	1.9101	.88593	22
39	.46407	.52390	1.9088	.88580	21
40	.46433	.52427	1.9074	.88566	20
41	.46458	.52464	1.9061	.88553	19
42	.46484	.52501	1.9047	.88539	18
43	.46510	.52538	1.9034	.88526	17
44	.46536	.52575	1.9020	.88512	16
45	.46561	.52613	1.9007	.88499	15
46	.46587	.52650	1.8993	.88485	14
47	.46613	.52687	1.8980	.88472	13
48	.46639	.52724	1.8967	.88458	12
49	.46664	.52761	1.8953	.88445	11
50	.46690	.52798	1.8940	.88431	10
51	.46716	.52836	1.8927	.88417	9
52	.46742	.52873	1.8913	.88404	8
53	.46767	.52910	1.8900	.88390	7
54	.46793	.52947	1.8887	.88377	6
55	.46819	.52985	1.8873	.88363	5
56	.46844	.53022	1.8860	.88349	4
57	.46870	.53059	1.8847	.88336	3
58	.46896	.53096	1.8834	.88322	2
59	.46921	.53134	1.8820	.88308	1
60	.46947	.53171	1.8807	.88295	0
′	Cos	Cot	Tan	Sin	′

117° (297°) (242°) **62°**

NATURAL FUNCTIONS (Continued)

28° (208°) — (331°) **151°**

′	Sin	Tan	Cot	Cos	′
0	.46947	.53171	1.8807	.88295	60
1	.46973	.53208	1.8794	.88281	59
2	.46999	.53246	1.8781	.88267	58
3	.47024	.53283	1.8768	.88254	57
4	.47050	.53320	1.8755	.88240	56
5	.47076	.53358	1.8741	.88226	55
6	.47101	.53395	1.8728	.88213	54
7	.47127	.53432	1.8715	.88199	53
8	.47153	.53470	1.8702	.88185	52
9	.47178	.53507	1.8689	.88172	51
10	.47204	.53545	1.8676	.88158	50
11	.47229	.53582	1.8663	.88144	49
12	.47255	.53620	1.8650	.88130	48
13	.47281	.53657	1.8637	.88117	47
14	.47306	.53694	1.8624	.88103	46
15	.47332	.53732	1.8611	.88089	45
16	.47358	.53769	1.8598	.88075	44
17	.47383	.53807	1.8585	.88062	43
18	.47409	.53844	1.8572	.88048	42
19	.47434	.53882	1.8559	.88034	41
20	.47460	.53920	1.8546	.88020	40
21	.47486	.53957	1.8533	.88006	39
22	.47511	.53995	1.8520	.87993	38
23	.47537	.54032	1.8507	.87979	37
24	.47562	.54070	1.8495	.87965	36
25	.47588	.54107	1.8482	.87951	35
26	.47614	.54145	1.8469	.87937	34
27	.47639	.54183	1.8456	.87923	33
28	.47665	.54220	1.8443	.87909	32
29	.47690	.54258	1.8430	.87896	31
30	.47716	.54296	1.8418	.87882	30
31	.47741	.54333	1.8405	.87868	29
32	.47767	.54371	1.8392	.87854	28
33	.47793	.54409	1.8379	.87840	27
34	.47818	.54446	1.8367	.87826	26
35	.47844	.54484	1.8354	.87812	25
36	.47869	.54522	1.8341	.87798	24
37	.47895	.54560	1.8329	.87784	23
38	.47920	.54597	1.8316	.87770	22
39	.47946	.54635	1.8303	.87756	21
40	.47971	.54673	1.8291	.87743	20
41	.47997	.54711	1.8278	.87729	19
42	.48022	.54748	1.8265	.87715	18
43	.48048	.54786	1.8253	.87701	17
44	.48073	.54824	1.8240	.87687	16
45	.48099	.54862	1.8228	.87673	15
46	.48124	.54900	1.8215	.87659	14
47	.48150	.54938	1.8202	.87645	13
48	.48175	.54975	1.8190	.87631	12
49	.48201	.55013	1.8177	.87617	11
50	.48226	.55051	1.8165	.87603	10
51	.48252	.55089	1.8152	.87589	9
52	.48277	.55127	1.8140	.87575	8
53	.48303	.55165	1.8127	.87561	7
54	.48328	.55203	1.8115	.87546	6
55	.48354	.55241	1.8103	.87532	5
56	.48379	.55279	1.8090	.87518	4
57	.48405	.55317	1.8078	.87504	3
58	.48430	.55355	1.8065	.87490	2
59	.48456	.55393	1.8053	.87476	1
60	.48481	.55431	1.8040	.87462	0
′	Cos	Cot	Tan	Sin	′

118° (298°) — (241°) **61°**

29° (209°) — (330°) **150°**

′	Sin	Tan	Cot	Cos	′
0	.48481	.55431	1.8040	.87462	60
1	.48506	.55469	1.8028	.87448	59
2	.48532	.55507	1.8016	.87434	58
3	.48557	.55545	1.8003	.87420	57
4	.48583	.55583	1.7991	.87406	56
5	.48608	.55621	1.7979	.87391	55
6	.48634	.55659	1.7966	.87377	54
7	.48659	.55697	1.7954	.87363	53
8	.48684	.55736	1.7942	.87349	52
9	.48710	.55774	1.7930	.87335	51
10	.48735	.55812	1.7917	.87321	50
11	.48761	.55850	1.7905	.87306	49
12	.48786	.55888	1.7893	.87292	48
13	.48811	.55926	1.7881	.87278	47
14	.48837	.55964	1.7868	.87264	46
15	.48862	.56003	1.7856	.87250	45
16	.48888	.56041	1.7844	.87235	44
17	.48913	.56079	1.7832	.87221	43
18	.48938	.56117	1.7820	.87207	42
19	.48964	.56156	1.7808	.87193	41
20	.48989	.56194	1.7796	.87178	40
21	.49014	.56232	1.7783	.87164	39
22	.49040	.56270	1.7771	.87150	38
23	.49065	.56309	1.7759	.87136	37
24	.49090	.56347	1.7747	.87121	36
25	.49116	.56385	1.7735	.87107	35
26	.49141	.56424	1.7723	.87093	34
27	.49166	.56462	1.7711	.87079	33
28	.49192	.56501	1.7699	.87064	32
29	.49217	.56539	1.7687	.87050	31
30	.49242	.56577	1.7675	.87036	30
31	.49268	.56616	1.7663	.87021	29
32	.49293	.56654	1.7651	.87007	28
33	.49318	.56693	1.7639	.86993	27
34	.49344	.56731	1.7627	.86978	26
35	.49369	.56769	1.7615	.86964	25
36	.49394	.56808	1.7603	.86949	24
37	.49419	.56846	1.7591	.86935	23
38	.49445	.56885	1.7579	.86921	22
39	.49470	.56923	1.7567	.86906	21
40	.49495	.56962	1.7556	.86892	20
41	.49521	.57000	1.7544	.86878	19
42	.49546	.57039	1.7532	.86863	18
43	.49571	.57078	1.7520	.86849	17
44	.49596	.57116	1.7508	.86834	16
45	.49622	.57155	1.7496	.86820	15
46	.49647	.57193	1.7485	.86805	14
47	.49672	.57232	1.7473	.86791	13
48	.49697	.57271	1.7461	.86777	12
49	.49723	.57309	1.7449	.86762	11
50	.49748	.57348	1.7437	.86748	10
51	.49773	.57386	1.7426	.86733	9
52	.49798	.57425	1.7414	.86719	8
53	.49824	.57464	1.7402	.86704	7
54	.49849	.57503	1.7391	.86690	6
55	.49874	.57541	1.7379	.86675	5
56	.49899	.57580	1.7367	.86661	4
57	.49924	.57619	1.7355	.86646	3
58	.49950	.57657	1.7344	.86632	2
59	.49975	.57696	1.7332	.86617	1
60	.50000	.57735	1.7321	.86603	0
′	Cos	Cot	Tan	Sin	′

119° (299°) — (240°) **60°**

NATURAL FUNCTIONS (Continued)

30° (210°) (329°) **149°**

′	Sin	Tan	Cot	Cos	′
0	.50000	.57735	1.7321	.86603	**60**
1	.50025	.57774	1.7309	.86588	59
2	.50050	.57813	1.7297	.86573	58
3	.50076	.57851	1.7286	.86559	57
4	.50101	.57890	1.7274	.86544	56
5	.50126	.57929	1.7262	.86530	**55**
6	.50151	.57968	1.7251	.86515	54
7	.50176	.58007	1.7239	.86501	53
8	.50201	.58046	1.7228	.86486	52
9	.50227	.58085	1.7216	.86471	51
10	.50252	.58124	1.7205	.86457	**50**
11	.50277	.58162	1.7193	.86442	49
12	.50302	.58201	1.7182	.86427	48
13	.50327	.58240	1.7170	.86413	47
14	.50352	.58279	1.7159	.86398	46
15	.50377	.58318	1.7147	.86384	**45**
16	.50403	.58357	1.7136	.86369	44
17	.50428	.58396	1.7124	.86354	43
18	.50453	.58435	1.7113	.86340	42
19	.50478	.58474	1.7102	.86325	41
20	.50503	.58513	1.7090	.86310	**40**
21	.50528	.58552	1.7079	.86295	39
22	.50553	.58591	1.7067	.86281	38
23	.50578	.58631	1.7056	.86266	37
24	.50603	.58670	1.7045	.86251	36
25	.50628	.58709	1.7033	.86237	**35**
26	.50654	.58748	1.7022	.86222	34
27	.50679	.58787	1.7011	.86207	33
28	.50704	.58826	1.6999	.86192	32
29	.50729	.58865	1.6988	.86178	31
30	.50754	.58905	1.6977	.86163	**30**
31	.50779	.58944	1.6965	.86148	29
32	.50804	.58983	1.6954	.86133	28
33	.50829	.59022	1.6943	.86119	27
34	.50854	.59061	1.6932	.86104	26
35	.50879	.59101	1.6920	.86089	**25**
36	.50904	.59140	1.6909	.86074	24
37	.50929	.59179	1.6898	.86059	23
38	.50954	.59218	1.6887	.86045	22
39	.50979	.59258	1.6875	.86030	21
40	.51004	.59297	1.6864	.86015	**20**
41	.51029	.59336	1.6853	.86000	19
42	.51054	.59376	1.6842	.85985	18
43	.51079	.59415	1.6831	.85970	17
44	.51104	.59454	1.6820	.85956	16
45	.51129	.59494	1.6808	.85941	**15**
46	.51154	.59533	1.6797	.85926	14
47	.51179	.59573	1.6786	.85911	13
48	.51204	.59612	1.6775	.85896	12
49	.51229	.59651	1.6764	.85881	11
50	.51254	.59691	1.6753	.85866	**10**
51	.51279	.59730	1.6742	.85851	9
52	.51304	.59770	1.6731	.85836	8
53	.51329	.59809	1.6720	.85821	7
54	.51354	.59849	1.6709	.85806	6
55	.51379	.59888	1.6698	.85792	**5**
56	.51404	.59928	1.6687	.85777	4
57	.51429	.59967	1.6676	.85762	3
58	.51454	.60007	1.6665	.85747	2
59	.51479	.60046	1.6654	.85732	1
60	.51504	.60086	1.6643	.85717	**0**
′	Cos	Cot	Tan	Sin	′

120° (300°) (239°) **59°**

31° (211°) (328°) **148°**

′	Sin	Tan	Cot	Cos	′
0	.51504	.60086	1.6643	.85717	**60**
1	.51529	.60126	1.6632	.85702	59
2	.51554	.60165	1.6621	.85687	58
3	.51579	.60205	1.6610	.85672	57
4	.51604	.60245	1.6599	.85657	56
5	.51628	.60284	1.6588	.85642	**55**
6	.51653	.60324	1.6577	.85627	54
7	.51678	.60364	1.6566	.85612	53
8	.51703	.60403	1.6555	.85597	52
9	.51728	.60443	1.6545	.85582	51
10	.51753	.60483	1.6534	.85567	**50**
11	.51778	.60522	1.6523	.85551	49
12	.51803	.60562	1.6512	.85536	48
13	.51828	.60602	1.6501	.85521	47
14	.51852	.60642	1.6490	.85506	46
15	.51877	.60681	1.6479	.85491	**45**
16	.51902	.60721	1.6469	.85476	44
17	.51927	.60761	1.6458	.85461	43
18	.51952	.60801	1.6447	.85446	42
19	.51977	.60841	1.6436	.85431	41
20	.52002	.60881	1.6426	.85416	**40**
21	.52026	.60921	1.6415	.85401	39
22	.52051	.60960	1.6404	.85385	38
23	.52076	.61000	1.6393	.85370	37
24	.52101	.61040	1.6383	.85355	36
25	.52126	.61080	1.6372	.85340	**35**
26	.52151	.61120	1.6361	.85325	34
27	.52175	.61160	1.6351	.85310	33
28	.52200	.61200	1.6340	.85294	32
29	.52225	.61240	1.6329	.85279	31
30	.52250	.61280	1.6319	.85264	**30**
31	.52275	.61320	1.6308	.85249	29
32	.52299	.61360	1.6297	.85234	28
33	.52324	.61400	1.6287	.85218	27
34	.52349	.61440	1.6276	.85203	26
35	.52374	.61480	1.6265	.85188	**25**
36	.52399	.61520	1.6255	.85173	24
37	.52423	.61561	1.6244	.85157	23
38	.52448	.61601	1.6234	.85142	22
39	.52473	.61641	1.6223	.85127	21
40	.52498	.61681	1.6212	.85112	**20**
41	.52522	.61721	1.6202	.85096	19
42	.52547	.61761	1.6191	.85081	18
43	.52572	.61801	1.6181	.85066	17
44	.52597	.61842	1.6170	.85051	16
45	.52621	.61882	1.6160	.85035	**15**
46	.52646	.61922	1.6149	.85020	14
47	.52671	.61962	1.6139	.85005	13
48	.52696	.62003	1.6128	.84989	12
49	.52720	.62043	1.6118	.84974	11
50	.52745	.62083	1.6107	.84959	**10**
51	.52770	.62124	1.6097	.84943	9
52	.52794	.62164	1.6087	.84928	8
53	.52819	.62204	1.6076	.84913	7
54	.52844	.62245	1.6066	.84897	6
55	.52869	.62285	1.6055	.84882	**5**
56	.52893	.62325	1.6045	.84866	4
57	.52918	.62366	1.6034	.84851	3
58	.52943	.62406	1.6024	.84836	2
59	.52967	.62446	1.6014	.84820	1
60	.52992	.62487	1.6003	.84805	**0**
′	Cos	Cot	Tan	Sin	′

121° (301°) (238°) **58°**

NATURAL FUNCTIONS (Continued)

32° (212°) (327°) 147°

′	Sin	Tan	Cot	Cos	′
0	.52992	.62487	1.6003	.84805	60
1	.53017	.62527	1.5993	.84789	59
2	.53041	.62568	1.5983	.84774	58
3	.53066	.62608	1.5972	.84759	57
4	.53091	.62649	1.5962	.84743	56
5	.53115	.62689	1.5952	.84728	55
6	.53140	.62730	1.5941	.84712	54
7	.53164	.62770	1.5931	.84697	53
8	.53189	.62811	1.5921	.84681	52
9	.53214	.62852	1.5911	.84666	51
10	.53238	.62892	1.5900	.84650	50
11	.53263	.62933	1.5890	.84635	49
12	.53288	.62973	1.5880	.84619	48
13	.53312	.63014	1.5869	.84604	47
14	.53337	.63055	1.5859	.84588	46
15	.53361	.63095	1.5849	.84573	45
16	.53386	.63136	1.5839	.84557	44
17	.53411	.63177	1.5829	.84542	43
18	.53435	.63217	1.5818	.84526	42
19	.53460	.63258	1.5808	.84511	41
20	.53484	.63299	1.5798	.84495	40
21	.53509	.63340	1.5788	.84480	39
22	.53534	.63380	1.5778	.84464	38
23	.53558	.63421	1.5768	.84448	37
24	.53583	.63462	1.5757	.84433	36
25	.53607	.63503	1.5747	.84417	35
26	.53632	.63544	1.5737	.84402	34
27	.53656	.63584	1.5727	.84386	33
28	.53681	.63625	1.5717	.84370	32
29	.53705	.63666	1.5707	.84355	31
30	.53730	.63707	1.5697	.84339	30
31	.53754	.63748	1.5687	.84324	29
32	.53779	.63789	1.5677	.84308	28
33	.53804	.63830	1.5667	.84292	27
34	.53828	.63871	1.5657	.84277	26
35	.53853	.63912	1.5647	.84261	25
36	.53877	.63953	1.5637	.84245	24
37	.53902	.63994	1.5627	.84230	23
38	.53926	.64035	1.5617	.84214	22
39	.53951	.64076	1.5607	.84198	21
40	.53975	.64117	1.5597	.84182	20
41	.54000	.64158	1.5587	.84167	19
42	.54024	.64199	1.5577	.84151	18
43	.54049	.64240	1.5567	.84135	17
44	.54073	.64281	1.5557	.84120	16
45	.54097	.64322	1.5547	.84104	15
46	.54122	.64363	1.5537	.84088	14
47	.54146	.64404	1.5527	.84072	13
48	.54171	.64446	1.5517	.84057	12
49	.54195	.64487	1.5507	.84041	11
50	.54220	.64528	1.5497	.84025	10
51	.54244	.64569	1.5487	.84009	9
52	.54269	.64610	1.5477	.83994	8
53	.54293	.64652	1.5468	.83978	7
54	.54317	.64693	1.5458	.83962	6
55	.54342	.64734	1.5448	.83946	5
56	.54366	.64775	1.5438	.83930	4
57	.54391	.64817	1.5428	.83915	3
58	.54415	.64858	1.5418	.83899	2
59	.54440	.64899	1.5408	.83883	1
60	.54464	.64941	1.5399	.83867	0
′	Cos	Cot	Tan	Sin	′

122° (302°) (237°) 57°

33° (213°) (326°) 146°

′	Sin	Tan	Cot	Cos	′
0	.54464	.64941	1.5399	.83867	60
1	.54488	.64982	1.5389	.83851	59
2	.54513	.65024	1.5379	.83835	58
3	.54537	.65065	1.5369	.83819	57
4	.54561	.65106	1.5359	.83804	56
5	.54586	.65148	1.5350	.83788	55
6	.54610	.65189	1.5340	.83772	54
7	.54635	.65231	1.5330	.83756	53
8	.54659	.65272	1.5320	.83740	52
9	.54683	.65314	1.5311	.83724	51
10	.54708	.65355	1.5301	.83708	50
11	.54732	.65397	1.5291	.83692	49
12	.54756	.65438	1.5282	.83676	48
13	.54781	.65480	1.5272	.83660	47
14	.54805	.65521	1.5262	.83645	46
15	.54829	.65563	1.5253	.83629	45
16	.54854	.65604	1.5243	.83613	44
17	.54878	.65646	1.5233	.83597	43
18	.54902	.65688	1.5224	.83581	42
19	.54927	.65729	1.5214	.83565	41
20	.54951	.65771	1.5204	.83549	40
21	.54975	.65813	1.5195	.83533	39
22	.54999	.65854	1.5185	.83517	38
23	.55024	.65896	1.5175	.83501	37
24	.55048	.65938	1.5166	.83485	36
25	.55072	.65980	1.5156	.83469	35
26	.55097	.66021	1.5147	.83453	34
27	.55121	.66063	1.5137	.83437	33
28	.55145	.66105	1.5127	.83421	32
29	.55169	.66147	1.5118	.83405	31
30	.55194	.66189	1.5108	.83389	30
31	.55218	.66230	1.5099	.83373	29
32	.55242	.66272	1.5089	.83356	28
33	.55266	.66314	1.5080	.83340	27
34	.55291	.66356	1.5070	.83324	26
35	.55315	.66398	1.5061	.83308	25
36	.55339	.66440	1.5051	.83292	24
37	.55363	.66482	1.5042	.83276	23
38	.55388	.66524	1.5032	.83260	22
39	.55412	.66566	1.5023	.83244	21
40	.55436	.66608	1.5013	.83228	20
41	.55460	.66650	1.5004	.83212	19
42	.55484	.66692	1.4994	.83195	18
43	.55509	.66734	1.4985	.83179	17
44	.55533	.66776	1.4975	.83163	16
45	.55557	.66818	1.4966	.83147	15
46	.55581	.66860	1.4957	.83131	14
47	.55605	.66902	1.4947	.83115	13
48	.55630	.66944	1.4938	.83098	12
49	.55654	.66986	1.4928	.83082	11
50	.55678	.67028	1.4919	.83066	10
51	.55702	.67071	1.4910	.83050	9
52	.55726	.67113	1.4900	.83034	8
53	.55750	.67155	1.4891	.83017	7
54	.55775	.67197	1.4882	.83001	6
55	.55799	.67239	1.4872	.82985	5
56	.55823	.67282	1.4863	.82969	4
57	.55847	.67324	1.4854	.82953	3
58	.55871	.67366	1.4844	.82936	2
59	.55895	.67409	1.4835	.82920	1
60	.55919	.67451	1.4826	.82904	0
′	Cos	Cot	Tan	Sin	′

123° (303°) (236°) 56°

NATURAL FUNCTIONS (Continued)

34° (214°) (325°) **145°**

′	Sin	Tan	Cot	Cos	′
0	.55919	.67451	1.4826	.82904	**60**
1	.55943	.67493	1.4816	.82887	59
2	.55968	.67536	1.4807	.82871	58
3	.55992	.67578	1.4798	.82855	57
4	.56016	.67620	1.4788	.82839	56
5	.56040	.67663	1.4779	.82822	**55**
6	.56064	.67705	1.4770	.82806	54
7	.56088	.67748	1.4761	.82790	53
8	.56112	.67790	1.4751	.82773	52
9	.56136	.67832	1.4742	.82757	51
10	.56160	.67875	1.4733	.82741	**50**
11	.56184	.67917	1.4724	.82724	49
12	.56208	.67960	1.4715	.82708	48
13	.56232	.68002	1.4705	.82692	47
14	.56256	.68045	1.4696	.82675	46
15	.56280	.68088	1.4687	.82659	**45**
16	.56305	.68130	1.4678	.82643	44
17	.56329	.68173	1.4669	.82626	43
18	.56353	.68215	1.4659	.82610	42
19	.56377	.68258	1.4650	.82593	41
20	.56401	.68301	1.4641	.82577	**40**
21	.56425	.68343	1.4632	.82561	39
22	.56449	.68386	1.4623	.82544	38
23	.56473	.68429	1.4614	.82528	37
24	.56497	.68471	1.4605	.82511	36
25	.56521	.68514	1.4596	.82495	**35**
26	.56545	.68557	1.4586	.82478	34
27	.56569	.68600	1.4577	.82462	33
28	.56593	.68642	1.4568	.82446	32
29	.56617	.68685	1.4559	.82429	31
30	.56641	.68728	1.4550	.82413	**30**
31	.56665	.68771	1.4541	.82396	29
32	.56689	.68814	1.4532	.82380	28
33	.56713	.68857	1.4523	.82363	27
34	.56736	.68900	1.4514	.82347	26
35	.56760	.68942	1.4505	.82330	**25**
36	.56784	.68985	1.4496	.82314	24
37	.56808	.69028	1.4487	.82297	23
38	.56832	.69071	1.4478	.82281	22
39	.56856	.69114	1.4469	.82264	21
40	.56880	.69157	1.4460	.82248	**20**
41	.56904	.69200	1.4451	.82231	19
42	.56928	.69243	1.4442	.82214	18
43	.56952	.69286	1.4433	.82198	17
44	.56976	.69329	1.4424	.82181	16
45	.57000	.69372	1.4415	.82165	**15**
46	.57024	.69416	1.4406	.82148	14
47	.57047	.69459	1.4397	.82132	13
48	.57071	.69502	1.4388	.82115	12
49	.57095	.69545	1.4379	.82098	11
50	.57119	.69588	1.4370	.82082	**10**
51	.57143	.69631	1.4361	.82065	9
52	.57167	.69675	1.4352	.82048	8
53	.57191	.69718	1.4344	.82032	7
54	.57215	.69761	1.4335	.82015	6
55	.57238	.69804	1.4326	.81999	**5**
56	.57262	.69847	1.4317	.81982	4
57	.57286	.69891	1.4308	.81965	3
58	.57310	.69934	1.4299	.81949	2
59	.57334	.69977	1.4290	.81932	1
60	.57358	.70021	1.4281	.81915	**0**
′	Cos	Cot	Tan	Sin	′

124° (304°) (235°) **55°**

35° (215°) (324°) **144°**

′	Sin	Tan	Cot	Cos	′
0	.57358	.70021	1.4281	.81915	**60**
1	.57381	.70064	1.4273	.81899	59
2	.57405	.70107	1.4264	.81882	58
3	.57429	.70151	1.4255	.81865	57
4	.57453	.70194	1.4246	.81848	56
5	.57477	.70238	1.4237	.81832	**55**
6	.57501	.70281	1.4229	.81815	54
7	.57524	.70325	1.4220	.81798	53
8	.57548	.70368	1.4211	.81782	52
9	.57572	.70412	1.4202	.81765	51
10	.57596	.70455	1.4193	.81748	**50**
11	.57619	.70499	1.4185	.81731	49
12	.57643	.70542	1.4176	.81714	48
13	.57667	.70586	1.4167	.81698	47
14	.57691	.70629	1.4158	.81681	46
15	.57715	.70673	1.4150	.81664	**45**
16	.57738	.70717	1.4141	.81647	44
17	.57762	.70760	1.4132	.81631	43
18	.57786	.70804	1.4124	.81614	42
19	.57810	.70848	1.4115	.81597	41
20	.57833	.70891	1.4106	.81580	**40**
21	.57857	.70935	1.4097	.81563	39
22	.57881	.70979	1.4089	.81546	38
23	.57904	.71023	1.4080	.81530	37
24	.57928	.71066	1.4071	.81513	36
25	.57952	.71110	1.4063	.81496	**35**
26	.57976	.71154	1.4054	.81479	34
27	.57999	.71198	1.4045	.81462	33
28	.58023	.71242	1.4037	.81445	32
29	.58047	.71285	1.4028	.81428	31
30	.58070	.71329	1.4019	.81412	**30**
31	.58094	.71373	1.4011	.81395	29
32	.58118	.71417	1.4002	.81378	28
33	.58141	.71461	1.3994	.81361	27
34	.58165	.71505	1.3985	.81344	26
35	.58189	.71549	1.3976	.81327	**25**
36	.58212	.71593	1.3968	.81310	24
37	.58236	.71637	1.3959	.81293	23
38	.58260	.71681	1.3951	.81276	22
39	.58283	.71725	1.3942	.81259	21
40	.58307	.71769	1.3934	.81242	**20**
41	.58330	.71813	1.3925	.81225	19
42	.58354	.71857	1.3916	.81208	18
43	.58378	.71901	1.3908	.81191	17
44	.58401	.71946	1.3899	.81174	16
45	.58425	.71990	1.3891	.81157	**15**
46	.58449	.72034	1.3882	.81140	14
47	.58472	.72078	1.3874	.81123	13
48	.58496	.72122	1.3865	.81106	12
49	.58519	.72167	1.3857	.81089	11
50	.58543	.72211	1.3848	.81072	**10**
51	.58567	.72255	1.3840	.81055	9
52	.58590	.72299	1.3831	.81038	8
53	.58614	.72344	1.3823	.81021	7
54	.58637	.72388	1.3814	.81004	6
55	.58661	.72432	1.3806	.80987	**5**
56	.58684	.72477	1.3798	.80970	4
57	.58708	.72521	1.3789	.80953	3
58	.58731	.72565	1.3781	.80936	2
59	.58755	.72610	1.3772	.80919	1
60	.58779	.72654	1.3764	.80902	**0**
′	Cos	Cot	Tan	Sin	′

125° (305°) (234°) **54°**

NATURAL FUNCTIONS (Continued)

36° (216°) (323°) **143°**

′	Sin	Tan	Cot	Cos	′
0	.58779	.72654	1.3764	.80902	60
1	.58802	.72699	1.3755	.80885	59
2	.58826	.72743	1.3747	.80867	58
3	.58849	.72788	1.3739	.80850	57
4	.58873	.72832	1.3730	.80833	56
5	.58896	.72877	1.3722	.80816	55
6	.58920	.72921	1.3713	.80799	54
7	.58943	.72966	1.3705	.80782	53
8	.58967	.73010	1.3697	.80765	52
9	.58990	.73055	1.3688	.80748	51
10	.59014	.73100	1.3680	.80730	50
11	.59037	.73144	1.3672	.80713	49
12	.59061	.73189	1.3663	.80696	48
13	.59084	.73234	1.3655	.80679	47
14	.59108	.73278	1.3647	.80662	46
15	.59131	.73323	1.3638	.80644	45
16	.59154	.73368	1.3630	.80627	44
17	.59178	.73413	1.3622	.80610	43
18	.59201	.73457	1.3613	.80593	42
19	.59225	.73502	1.3605	.80576	41
20	.59248	.73547	1.3597	.80558	40
21	.59272	.73592	1.3588	.80541	39
22	.59295	.73637	1.3580	.80524	38
23	.59318	.73681	1.3572	.80507	37
24	.59342	.73726	1.3564	.80489	36
25	.59365	.73771	1.3555	.80472	35
26	.59389	.73816	1.3547	.80455	34
27	.59412	.73861	1.3539	.80438	33
28	.59436	.73906	1.3531	.80420	32
29	.59459	.73951	1.3522	.80403	31
30	.59482	.73996	1.3514	.80386	30
31	.59506	.74041	1.3506	.80368	29
32	.59529	.74086	1.3498	.80351	28
33	.59552	.74131	1.3490	.80334	27
34	.59576	.74176	1.3481	.80316	26
35	.59599	.74221	1.3473	.80299	25
36	.59622	.74267	1.3465	.80282	24
37	.59646	.74312	1.3457	.80264	23
38	.59669	.74357	1.3449	.80247	22
39	.59693	.74402	1.3440	.80230	21
40	.59716	.74447	1.3432	.80212	20
41	.59739	.74492	1.3424	.80195	19
42	.59763	.74538	1.3416	.80178	18
43	.59786	.74583	1.3408	.80160	17
44	.59809	.74628	1.3400	.80143	16
45	.59832	.74674	1.3392	.80125	15
46	.59856	.74719	1.3384	.80108	14
47	.59879	.74764	1.3375	.80091	13
48	.59902	.74810	1.3367	.80073	12
49	.59926	.74855	1.3359	.80056	11
50	.59949	.74900	1.3351	.80038	10
51	.59972	.74946	1.3343	.80021	9
52	.59995	.74991	1.3335	.80003	8
53	.60019	.75037	1.3327	.79986	7
54	.60042	.75082	1.3319	.79968	6
55	.60065	.75128	1.3311	.79951	5
56	.60089	.75173	1.3303	.79934	4
57	.60112	.75219	1.3295	.79916	3
58	.60135	.75264	1.3287	.79899	2
59	.60158	.75310	1.3278	.79881	1
60	.60182	.75355	1.3270	.79864	0
′	Cos	Cot	Tan	Sin	′

126° (306°) (233°) **53°**

37° (217°) (322°) **142°**

′	Sin	Tan	Cot	Cos	′
0	.60182	.75355	1.3270	.79864	60
1	.60205	.75401	1.3262	.79846	59
2	.60228	.75447	1.3254	.79829	58
3	.60251	.75492	1.3246	.79811	57
4	.60274	.75538	1.3238	.79793	56
5	.60298	.75584	1.3230	.79776	55
6	.60321	.75629	1.3222	.79758	54
7	.60344	.75675	1.3214	.79741	53
8	.60367	.75721	1.3206	.79723	52
9	.60390	.75767	1.3198	.79706	51
10	.60414	.75812	1.3190	.79688	50
11	.60437	.75858	1.3182	.79671	49
12	.60460	.75904	1.3175	.79653	48
13	.60483	.75950	1.3167	.79635	47
14	.60506	.75996	1.3159	.79618	46
15	.60529	.76042	1.3151	.79600	45
16	.60553	.76088	1.3143	.79583	44
17	.60576	.76134	1.3135	.79565	43
18	.60599	.76180	1.3127	.79547	42
19	.60622	.76226	1.3119	.79530	41
20	.60645	.76272	1.3111	.79512	40
21	.60668	.76318	1.3103	.79494	39
22	.60691	.76364	1.3095	.79477	38
23	.60714	.76410	1.3087	.79459	37
24	.60738	.76456	1.3079	.79441	36
25	.60761	.76502	1.3072	.79424	35
26	.60784	.76548	1.3064	.79406	34
27	.60807	.76594	1.3056	.79388	33
28	.60830	.76640	1.3048	.79371	32
29	.60853	.76686	1.3040	.79353	31
30	.60876	.76733	1.3032	.79335	30
31	.60899	.76779	1.3024	.79318	29
32	.60922	.76825	1.3017	.79300	28
33	.60945	.76871	1.3009	.79282	27
34	.60968	.76918	1.3001	.79264	26
35	.60991	.76964	1.2993	.79247	25
36	.61015	.77010	1.2985	.79229	24
37	.61038	.77057	1.2977	.79211	23
38	.61061	.77103	1.2970	.79193	22
39	.61084	.77149	1.2962	.79176	21
40	.61107	.77196	1.2954	.79158	20
41	.61130	.77242	1.2946	.79140	19
42	.61153	.77289	1.2938	.79122	18
43	.61176	.77335	1.2931	.79105	17
44	.61199	.77382	1.2923	.79087	16
45	.61222	.77428	1.2915	.79069	15
46	.61245	.77475	1.2907	.79051	14
47	.61268	.77521	1.2900	.79033	13
48	.61291	.77568	1.2892	.79016	12
49	.61314	.77615	1.2884	.78998	11
50	.61337	.77661	1.2876	.78980	10
51	.61360	.77708	1.2869	.78962	9
52	.61383	.77754	1.2861	.78944	8
53	.61406	.77801	1.2853	.78926	7
54	.61429	.77848	1.2846	.78908	6
55	.61451	.77895	1.2838	.78891	5
56	.61474	.77941	1.2830	.78873	4
57	.61497	.77988	1.2822	.78855	3
58	.61520	.78035	1.2815	.78837	2
59	.61543	.78082	1.2807	.78819	1
60	.61566	.78129	1.2799	.78801	0
′	Cos	Cot	Tan	Sin	′

127° (307°) (232°) **52°**

NATURAL FUNCTIONS (Continued)

38° (218°) — (321°) **141°**

′	Sin	Tan	Cot	Cos	′
0	.61566	.78129	1.2799	.78801	60
1	.61589	.78175	1.2792	.78783	59
2	.61612	.78222	1.2784	.78765	58
3	.61635	.78269	1.2776	.78747	57
4	.61658	.78316	1.2769	.78729	56
5	.61681	.78363	1.2761	.78711	55
6	.61704	.78410	1.2753	.78694	54
7	.61726	.78457	1.2746	.78676	53
8	.61749	.78504	1.2738	.78658	52
9	.61772	.78551	1.2731	.78640	51
10	.61795	.78598	1.2723	.78622	50
11	.61818	.78645	1.2715	.78604	49
12	.61841	.78692	1.2708	.78586	48
13	.61864	.78739	1.2700	.78568	47
14	.61887	.78786	1.2693	.78550	46
15	.61909	.78834	1.2685	.78532	45
16	.61932	.78881	1.2677	.78514	44
17	.61955	.78928	1.2670	.78496	43
18	.61978	.78975	1.2662	.78478	42
19	.62001	.79022	1.2655	.78460	41
20	.62024	.79070	1.2647	.78442	40
21	.62046	.79117	1.2640	.78424	39
22	.62069	.79164	1.2632	.78405	38
23	.62092	.79212	1.2624	.78387	37
24	.62115	.79259	1.2617	.78369	36
25	.62138	.79306	1.2609	.78351	35
26	.62160	.79354	1.2602	.78333	34
27	.62183	.79401	1.2594	.78315	33
28	.62206	.79449	1.2587	.78297	32
29	.62229	.79496	1.2579	.78279	31
30	.62251	.79544	1.2572	.78261	30
31	.62274	.79591	1.2564	.78243	29
32	.62297	.79639	1.2557	.78225	28
33	.62320	.79686	1.2549	.78206	27
34	.62342	.79734	1.2542	.78188	26
35	.62365	.79781	1.2534	.78170	25
36	.62388	.79829	1.2527	.78152	24
37	.62411	.79877	1.2519	.78134	23
38	.62433	.79924	1.2512	.78116	22
39	.62456	.79972	1.2504	.78098	21
40	.62479	.80020	1.2497	.78079	20
41	.62502	.80067	1.2489	.78061	19
42	.62524	.80115	1.2482	.78043	18
43	.62547	.80163	1.2475	.78025	17
44	.62570	.80211	1.2467	.78007	16
45	.62592	.80258	1.2460	.77988	15
46	.62615	.80306	1.2452	.77970	14
47	.62638	.80354	1.2445	.77952	13
48	.62660	.80402	1.2437	.77934	12
49	.62683	.80450	1.2430	.77916	11
50	.62706	.80498	1.2423	.77897	10
51	.62728	.80546	1.2415	.77879	9
52	.62751	.80594	1.2408	.77861	8
53	.62774	.80642	1.2401	.77843	7
54	.62796	.80690	1.2393	.77824	6
55	.62819	.80738	1.2386	.77806	5
56	.62842	.80786	1.2378	.77788	4
57	.62864	.80834	1.2371	.77769	3
58	.62887	.80882	1.2364	.77751	2
59	.62909	.80930	1.2356	.77733	1
60	.62932	.80978	1.2349	.77715	0
′	Cos	Cot	Tan	Sin	′

128° (308°) — (231°) **51°**

39° (219°) — (320°) **140°**

′	Sin	Tan	Cot	Cos	′
0	.62932	.80978	1.2349	.77715	60
1	.62955	.81027	1.2342	.77696	59
2	.62977	.81075	1.2334	.77678	58
3	.63000	.81123	1.2327	.77660	57
4	.63022	.81171	1.2320	.77641	56
5	.63045	.81220	1.2312	.77623	55
6	.63068	.81268	1.2305	.77605	54
7	.63090	.81316	1.2298	.77586	53
8	.63113	.81364	1.2290	.77568	52
9	.63135	.81413	1.2283	.77550	51
10	.63158	.81461	1.2276	.77531	50
11	.63180	.81510	1.2268	.77513	49
12	.63203	.81558	1.2261	.77494	48
13	.63225	.81606	1.2254	.77476	47
14	.63248	.81655	1.2247	.77458	46
15	.63271	.81703	1.2239	.77439	45
16	.63293	.81752	1.2232	.77421	44
17	.63316	.81800	1.2225	.77402	43
18	.63338	.81849	1.2218	.77384	42
19	.63361	.81898	1.2210	.77366	41
20	.63383	.81946	1.2203	.77347	40
21	.63406	.81995	1.2196	.77329	39
22	.63428	.82044	1.2189	.77310	38
23	.63451	.82092	1.2181	.77292	37
24	.63473	.82141	1.2174	.77273	36
25	.63496	.82190	1.2167	.77255	35
26	.63518	.82238	1.2160	.77236	34
27	.63540	.82287	1.2153	.77218	33
28	.63563	.82336	1.2145	.77199	32
29	.63585	.82385	1.2138	.77181	31
30	.63608	.82434	1.2131	.77162	30
31	.63630	.82483	1.2124	.77144	29
32	.63653	.82531	1.2117	.77125	28
33	.63675	.82580	1.2109	.77107	27
34	.63698	.82629	1.2102	.77088	26
35	.63720	.82678	1.2095	.77070	25
36	.63742	.82727	1.2088	.77051	24
37	.63765	.82776	1.2081	.77033	23
38	.63787	.82825	1.2074	.77014	22
39	.63810	.82874	1.2066	.76996	21
40	.63832	.82923	1.2059	.76977	20
41	.63854	.82972	1.2052	.76959	19
42	.63877	.83022	1.2045	.76940	18
43	.63899	.83071	1.2038	.76921	17
44	.63922	.83120	1.2031	.76903	16
45	.63944	.83169	1.2024	.76884	15
46	.63966	.83218	1.2017	.76866	14
47	.63989	.83268	1.2009	.76847	13
48	.64011	.83317	1.2002	.76828	12
49	.64033	.83366	1.1995	.76810	11
50	.64056	.83415	1.1988	.76791	10
51	.64078	.83465	1.1981	.76772	9
52	.64100	.83514	1.1974	.76754	8
53	.64123	.83564	1.1967	.76735	7
54	.64145	.83613	1.1960	.76717	6
55	.64167	.83662	1.1953	.76698	5
56	.64190	.83712	1.1946	.76679	4
57	.64212	.83761	1.1939	.76661	3
58	.64234	.83811	1.1932	.76642	2
59	.64256	.83860	1.1925	.76623	1
60	.64279	.83910	1.1918	.76604	0
′	Cos	Cot	Tan	Sin	′

129° (309°) — (230°) **50°**

NATURAL FUNCTIONS (Continued)

40° (220°) (319°) **139°**

′	Sin	Tan	Cot	Cos	′
0	.64279	.83910	1.1918	.76604	**60**
1	.64301	.83960	1.1910	.76586	59
2	.64323	.84009	1.1903	.76567	58
3	.64346	.84059	1.1896	.76548	57
4	.64368	.84108	1.1889	.76530	56
5	.64390	.84158	1.1882	.76511	**55**
6	.64412	.84208	1.1875	.76492	54
7	.64435	.84258	1.1868	.76473	53
8	.64457	.84307	1.1861	.76455	52
9	.64479	.84357	1.1854	.76436	51
10	.64501	.84407	1.1847	.76417	**50**
11	.64524	.84457	1.1840	.76398	49
12	.64546	.84507	1.1833	.76380	48
13	.64568	.84556	1.1826	.76361	47
14	.64590	.84606	1.1819	.76342	46
15	.64612	.84656	1.1812	.76323	**45**
16	.64635	.84706	1.1806	.76304	44
17	.64657	.84756	1.1799	.76286	43
18	.64679	.84806	1.1792	.76267	42
19	.64701	.84856	1.1785	.76248	41
20	.64723	.84906	1.1778	.76229	**40**
21	.64746	.84956	1.1771	.76210	39
22	.64768	.85006	1.1764	.76192	38
23	.64790	.85057	1.1757	.76173	37
24	.64812	.85107	1.1750	.76154	36
25	.64834	.85157	1.1743	.76135	**35**
26	.64856	.85207	1.1736	.76116	34
27	.64878	.85257	1.1729	.76097	33
28	.64901	.85308	1.1722	.76078	32
29	.64923	.85358	1.1715	.76059	31
30	.64945	.85408	1.1708	.76041	**30**
31	.64967	.85458	1.1702	.76022	29
32	.64989	.85509	1.1695	.76003	28
33	.65011	.85559	1.1688	.75984	27
34	.65033	.85609	1.1681	.75965	26
35	.65055	.85660	1.1674	.75946	**25**
36	.65077	.85710	1.1667	.75927	24
37	.65100	.85761	1.1660	.75908	23
38	.65122	.85811	1.1653	.75889	22
39	.65144	.85862	1.1647	.75870	21
40	.65166	.85912	1.1640	.75851	**20**
41	.65188	.85963	1.1633	.75832	19
42	.65210	.86014	1.1626	.75813	18
43	.65232	.86064	1.1619	.75794	17
44	.65254	.86115	1.1612	.75775	16
45	.65276	.86166	1.1606	.75756	**15**
46	.65298	.86216	1.1599	.75738	14
47	.65320	.86267	1.1592	.75719	13
48	.65342	.86318	1.1585	.75700	12
49	.65364	.86368	1.1578	.75680	11
50	.65386	.86419	1.1571	.75661	**10**
51	.65408	.86470	1.1565	.75642	9
52	.65430	.86521	1.1558	.75623	8
53	.65452	.86572	1.1551	.75604	7
54	.65474	.86623	1.1544	.75585	6
55	.65496	.86674	1.1538	.75566	**5**
56	.65518	.86725	1.1531	.75547	4
57	.65540	.86776	1.1524	.75528	3
58	.65562	.86827	1.1517	.75509	2
59	.65584	.86878	1.1510	.75490	1
60	.65606	.86929	1.1504	.75471	**0**
′	Cos	Cot	Tan	Sin	′

130° (310°) (229°) **49°**

41° (221°) (318°) **138°**

′	Sin	Tan	Cot	Cos	′
0	.65606	.86929	1.1504	.75471	**60**
1	.65628	.86980	1.1497	.75452	59
2	.65650	.87031	1.1490	.75433	58
3	.65672	.87082	1.1483	.75414	57
4	.65694	.87133	1.1477	.75395	56
5	.65716	.87184	1.1470	.75375	**55**
6	.65738	.87236	1.1463	.75356	54
7	.65759	.87287	1.1456	.75337	53
8	.65781	.87338	1.1450	.75318	52
9	.65803	.87389	1.1443	.75299	51
10	.65825	.87441	1.1436	.75280	**50**
11	.65847	.87492	1.1430	.75261	49
12	.65869	.87543	1.1423	.75241	48
13	.65891	.87595	1.1416	.75222	47
14	.65913	.87646	1.1410	.75203	46
15	.65935	.87698	1.1403	.75184	**45**
16	.65956	.87749	1.1396	.75165	44
17	.65978	.87801	1.1389	.75146	43
18	.66000	.87852	1.1383	.75126	42
19	.66022	.87904	1.1376	.75107	41
20	.66044	.87955	1.1369	.75088	**40**
21	.66066	.88007	1.1363	.75069	39
22	.66088	.88059	1.1356	.75050	38
23	.66109	.88110	1.1349	.75030	37
24	.66131	.88162	1.1343	.75011	36
25	.66153	.88214	1.1336	.74992	**35**
26	.66175	.88265	1.1329	.74973	34
27	.66197	.88317	1.1323	.74953	33
28	.66218	.88369	1.1316	.74934	32
29	.66240	.88421	1.1310	.74915	31
30	.66262	.88473	1.1303	.74896	**30**
31	.66284	.88524	1.1296	.74876	29
32	.66306	.88576	1.1290	.74857	28
33	.66327	.88628	1.1283	.74838	27
34	.66349	.88680	1.1276	.74818	26
35	.66371	.88732	1.1270	.74799	**25**
36	.66393	.88784	1.1263	.74780	24
37	.66414	.88836	1.1257	.74760	23
38	.66436	.88888	1.1250	.74741	22
39	.66458	.88940	1.1243	.74722	21
40	.66480	.88992	1.1237	.74703	**20**
41	.66501	.89045	1.1230	.74683	19
42	.66523	.89097	1.1224	.74664	18
43	.66545	.89149	1.1217	.74644	17
44	.66566	.89201	1.1211	.74625	16
45	.66588	.89253	1.1204	.74606	**15**
46	.66610	.89306	1.1197	.74586	14
47	.66632	.89358	1.1191	.74567	13
48	.66653	.89410	1.1184	.74548	12
49	.66675	.89463	1.1178	.74528	11
50	.66697	.89515	1.1171	.74509	**10**
51	.66718	.89567	1.1165	.74489	9
52	.66740	.89620	1.1158	.74470	8
53	.66762	.89672	1.1152	.74451	7
54	.66783	.89725	1.1145	.74431	6
55	.66805	.89777	1.1139	.74412	**5**
56	.66827	.89830	1.1132	.74392	4
57	.66848	.89883	1.1126	.74373	3
58	.66870	.89935	1.1119	.74353	2
59	.66891	.89988	1.1113	.74334	1
60	.66913	.90040	1.1106	.74314	**0**
′	Cos	Cot	Tan	Sin	′

131° (311°) (228°) **48°**

NATURAL FUNCTIONS (Continued)

42° (222°) (317°) **137°**

′	Sin	Tan	Cot	Cos	′
0	.66913	.90040	1.1106	.74314	**60**
1	.66935	.90093	1.1100	.74295	59
2	.66956	.90146	1.1093	.74276	58
3	.66978	.90199	1.1087	.74256	57
4	.66999	.90251	1.1080	.74237	56
5	.67021	.90304	1.1074	.74217	**55**
6	.67043	.90357	1.1067	.74198	54
7	.67064	.90410	1.1061	.74178	53
8	.67086	.90463	1.1054	.74159	52
9	.67107	.90516	1.1048	.74139	51
10	.67129	.90569	1.1041	.74120	**50**
11	.67151	.90621	1.1035	.74100	49
12	.67172	.90674	1.1028	.74080	48
13	.67194	.90727	1.1022	.74061	47
14	.67215	.90781	1.1016	.74041	46
15	.67237	.90834	1.1009	.74022	**45**
16	.67258	.90887	1.1003	.74002	44
17	.67280	.90940	1.0996	.73983	43
18	.67301	.90993	1.0990	.73963	42
19	.67323	.91046	1.0983	.73944	41
20	.67344	.91099	1.0977	.73924	**40**
21	.67366	.91153	1.0971	.73904	39
22	.67387	.91206	1.0964	.73885	38
23	.67409	.91259	1.0958	.73865	37
24	.67430	.91313	1.0951	.73846	36
25	.67452	.91366	1.0945	.73826	**35**
26	.67473	.91419	1.0939	.73806	34
27	.67495	.91473	1.0932	.73787	33
28	.67516	.91526	1.0926	.73767	32
29	.67538	.91580	1.0919	.73747	31
30	.67559	.91633	1.0913	.73728	**30**
31	.67580	.91687	1.0907	.73708	29
32	.67602	.91740	1.0900	.73688	28
33	.67623	.91794	1.0894	.73669	27
34	.67645	.91847	1.0888	.73649	26
35	.67666	.91901	1.0881	.73629	**25**
36	.67688	.91955	1.0875	.73610	24
37	.67709	.92008	1.0869	.73590	23
38	.67730	.92062	1.0862	.73570	22
39	.67752	.92116	1.0856	.73551	21
40	.67773	.92170	1.0850	.73531	**20**
41	.67795	.92224	1.0843	.73511	19
42	.67816	.92277	1.0837	.73491	18
43	.67837	.92331	1.0831	.73472	17
44	.67859	.92385	1.0824	.73452	16
45	.67880	.92439	1.0818	.73432	**15**
46	.67901	.92493	1.0812	.73413	14
47	.67923	.92547	1.0805	.73393	13
48	.67944	.92601	1.0799	.73373	12
49	.67965	.92655	1.0793	.73353	11
50	.67987	.92709	1.0786	.73333	**10**
51	.68008	.92763	1.0780	.73314	9
52	.68029	.92817	1.0774	.73294	8
53	.68051	.92872	1.0768	.73274	7
54	.68072	.92926	1.0761	.73254	6
55	.68093	.92980	1.0755	.73234	**5**
56	.68115	.93034	1.0749	.73215	4
57	.68136	.93088	1.0742	.73195	3
58	.68157	.93143	1.0736	.73175	2
59	.68179	.93197	1.0730	.73155	1
60	.68200	.93252	1.0724	.73135	**0**
′	Cos	Cot	Tan	Sin	′

132° (312°) (227°) **47°**

43° (223°) (316°) **136°**

′	Sin	Tan	Cot	Cos	′
0	.68200	.93252	1.0724	.73135	**60**
1	.68221	.93306	1.0717	.73116	59
2	.68242	.93360	1.0711	.73096	58
3	.68264	.93415	1.0705	.73076	57
4	.68285	.93469	1.0699	.73056	56
5	.68306	.93524	1.0692	.73036	**55**
6	.68327	.93578	1.0686	.73016	54
7	.68349	.93633	1.0680	.72996	53
8	.68370	.93688	1.0674	.72976	52
9	.68391	.93742	1.0668	.72957	51
10	.68412	.93797	1.0661	.72937	**50**
11	.68434	.93852	1.0655	.72917	49
12	.68455	.93906	1.0649	.72897	48
13	.68476	.93961	1.0643	.72877	47
14	.68497	.94016	1.0637	.72857	46
15	.68518	.94071	1.0630	.72837	**45**
16	.68539	.94125	1.0624	.72817	44
17	.68561	.94180	1.0618	.72797	43
18	.68582	.94235	1.0612	.72777	42
19	.68603	.94290	1.0606	.72757	41
20	.68624	.94345	1.0599	.72737	**40**
21	.68645	.94400	1.0593	.72717	39
22	.68666	.94455	1.0587	.72697	38
23	.68688	.94510	1.0581	.72677	37
24	.68709	.94565	1.0575	.72657	36
25	.68730	.94620	1.0569	.72637	**35**
26	.68751	.94676	1.0562	.72617	34
27	.68772	.94731	1.0556	.72597	33
28	.68793	.94786	1.0550	.72577	32
29	.68814	.94841	1.0544	.72557	31
30	.68835	.94896	1.0538	.72537	**30**
31	.68857	.94952	1.0532	.72517	29
32	.68878	.95007	1.0526	.72497	28
33	.68899	.95062	1.0519	.72477	27
34	.68920	.95118	1.0513	.72457	26
35	.68941	.95173	1.0507	.72437	**25**
36	.68962	.95229	1.0501	.72417	24
37	.68983	.95284	1.0495	.72397	23
38	.69004	.95340	1.0489	.72377	22
39	.69025	.95395	1.0483	.72357	21
40	.69046	.95451	1.0477	.72337	**20**
41	.69067	.95506	1.0470	.72317	19
42	.69088	.95562	1.0464	.72297	18
43	.69109	.95618	1.0458	.72277	17
44	.69130	.95673	1.0452	.72257	16
45	.69151	.95729	1.0446	.72236	**15**
46	.69172	.95785	1.0440	.72216	14
47	.69193	.95841	1.0434	.72196	13
48	.69214	.95897	1.0428	.72176	12
49	.69235	.95952	1.0422	.72156	11
50	.69256	.96008	1.0416	.72136	**10**
51	.69277	.96064	1.0410	.72116	9
52	.69298	.96120	1.0404	.72095	8
53	.69319	.96176	1.0398	.72075	7
54	.69340	.96232	1.0392	.72055	6
55	.69361	.96288	1.0385	.72035	**5**
56	.69382	.96344	1.0379	.72015	4
57	.69403	.96400	1.0373	.71995	3
58	.69424	.96457	1.0367	.71974	2
59	.69445	.96513	1.0361	.71954	1
60	.69466	.96569	1.0355	.71934	**0**
′	Cos	Cot	Tan	Sin	′

133° (313°) (226°) **46°**

NATURAL FUNCTIONS (Continued)

44° (224°) (315°) **135°**

′	Sin	Tan	Cot	Cos	′
0	.69466	.96569	1.0355	.71934	**60**
1	.69487	.96625	1.0349	.71914	59
2	.69508	.96681	1.0343	.71894	58
3	.69529	.96738	1.0337	.71873	57
4	.69549	.96794	1.0331	.71853	56
5	.69570	.96850	1.0325	.71833	**55**
6	.69591	.96907	1.0319	.71813	54
7	.69612	.96963	1.0313	.71792	53
8	.69633	.97020	1.0307	.71772	52
9	.69654	.97076	1.0301	.71752	51
10	.69675	.97133	1.0295	.71732	**50**
11	.69696	.97189	1.0289	.71711	49
12	.69717	.97246	1.0283	.71691	48
13	.69737	.97302	1.0277	.71671	47
14	.69758	.97359	1.0271	.71650	46
15	.69779	.97416	1.0265	.71630	**45**
16	.69800	.97472	1.0259	.71610	44
17	.69821	.97529	1.0253	.71590	43
18	.69842	.97586	1.0247	.71569	42
19	.69862	.97643	1.0241	.71549	41
20	.69883	.97700	1.0235	.71529	**40**
21	.69904	.97756	1.0230	.71508	39
22	.69925	.97813	1.0224	.71488	38
23	.69946	.97870	1.0218	.71468	37
24	.69966	.97927	1.0212	.71447	36
25	.69987	.97984	1.0206	.71427	**35**
26	.70008	.98041	1.0200	.71407	34
27	.70029	.98098	1.0194	.71386	33
28	.70049	.98155	1.0188	.71366	32
29	.70070	.98213	1.0182	.71345	31
30	.70091	.98270	1.0176	.71325	**30**
31	.70112	.98327	1.0170	.71305	29
32	.70132	.98384	1.0164	.71284	28
33	.70153	.98441	1.0158	.71264	27
34	.70174	.98499	1.0152	.71243	26
35	.70195	.98556	1.0147	.71223	**25**
36	.70215	.98613	1.0141	.71203	24
37	.70236	.98671	1.0135	.71182	23
38	.70257	.98728	1.0129	.71162	22
39	.70277	.98786	1.0123	.71141	21
40	.70298	.98843	1.0117	.71121	**20**
41	.70319	.98901	1.0111	.71100	19
42	.70339	.98958	1.0105	.71080	18
43	.70360	.99016	1.0099	.71059	17
44	.70381	.99073	1.0094	.71039	16
45	.70401	.99131	1.0088	.71019	**15**
46	.70422	.99189	1.0082	.70998	14
47	.70443	.99247	1.0076	.70978	13
48	.70463	.99304	1.0070	.70957	12
49	.70484	.99362	1.0064	.70937	11
50	.70505	.99420	1.0058	.70916	**10**
51	.70525	.99478	1.0052	.70896	9
52	.70546	.99536	1.0047	.70875	8
53	.70567	.99594	1.0041	.70855	7
54	.70587	.99652	1.0035	.70834	6
55	.70608	.99710	1.0029	.70813	**5**
56	.70628	.99768	1.0023	.70793	4
57	.70649	.99826	1.0017	.70772	3
58	.70670	.99884	1.0012	.70752	2
59	.70690	.99942	1.0006	.70731	1
60	.70711	1.0000	1.0000	.70711	**0**
′	Cos	Cot	Tan	Sin	′

134° (314°) (225°) **45°**